COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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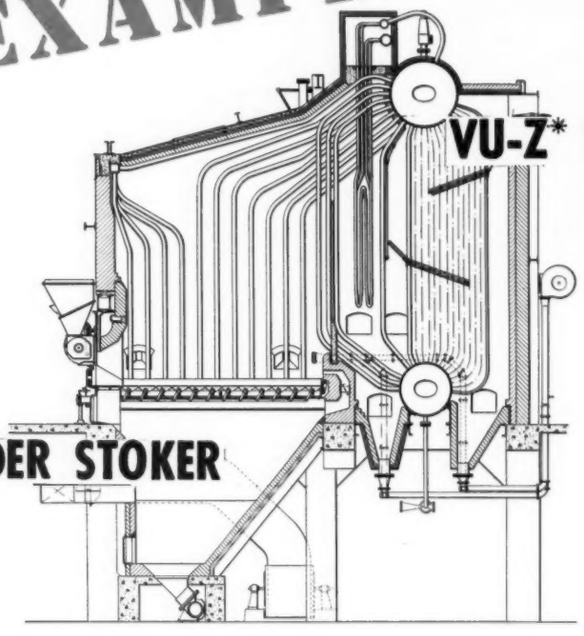
Photo by Roy Pinney

High-Pressure Boiler-Feed-Pump Practice ▶

Prevention of Deposits in Recirculating Systems ▶

With any type of stoker firing You can have the advantages of VU STEAM GENERATOR DESIGN

EXAMPLE NO. 1



No matter which one of various types of stokers is the logical choice for a particular installation, the VU-Z Steam Generator can be adapted to it with definite advantages.

For stoker firing, furnace volume and shape are of primary importance. In the VU-Z design these factors are unusually favorable. Its furnace contour makes the best use of the available space and therefore provides maximum furnace volume. The overall design of the unit permits any or all of the three principal furnace dimensions to be varied without altering the basic design of the boiler.

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** The VU-Z Steam Generator provides the advantages of Combustion Engineering's well-known VU Unit with a furnace and arrangement of heating surface especially adapted for stoker firing.*

A698

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200 Madison Avenue New York, New York

C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME FOURTEEN NUMBER FIVE

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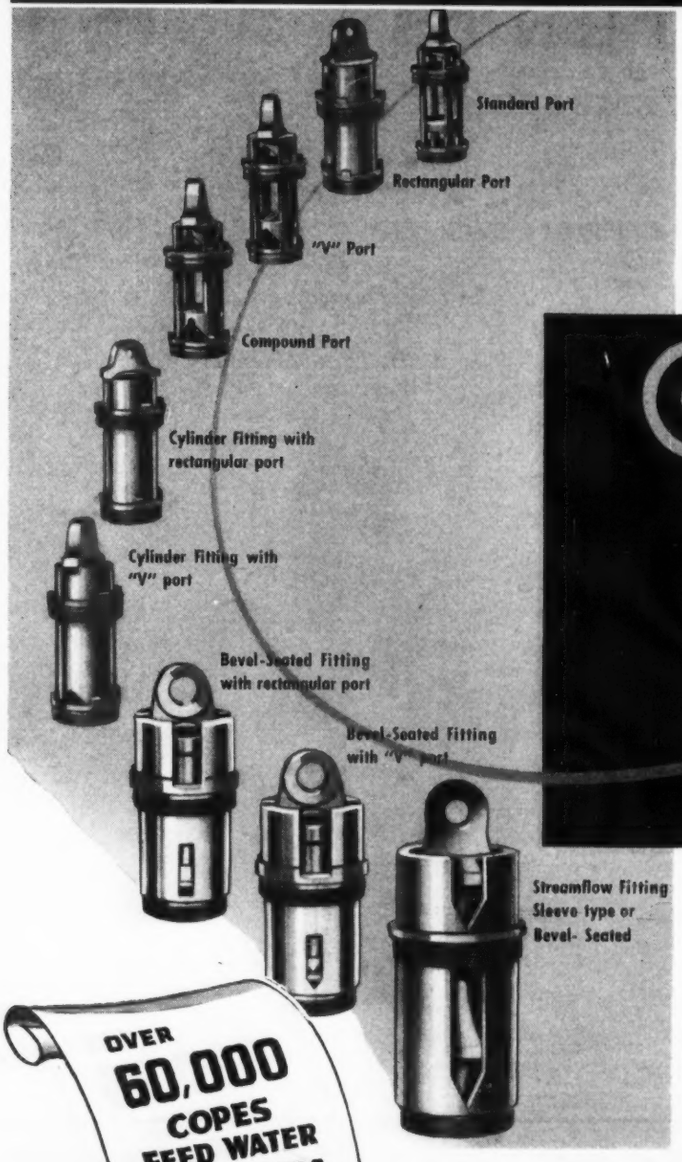

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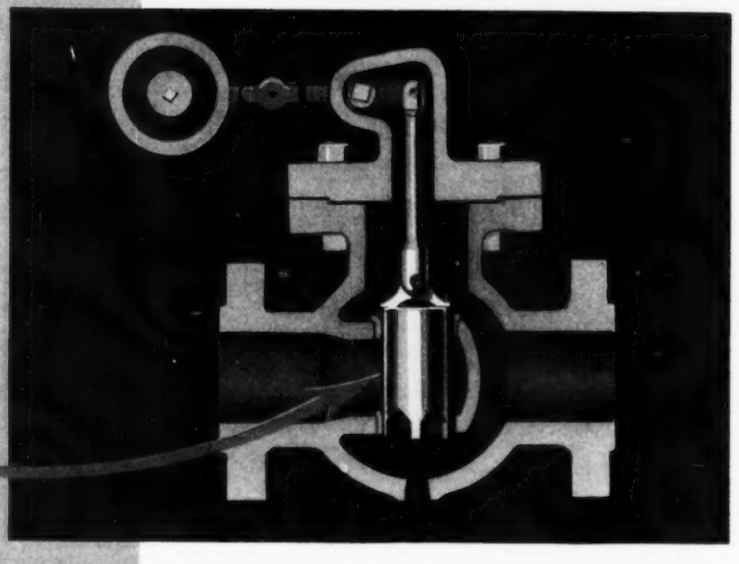

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EDITORIAL

Timely Symposiums

Symposiums, variously referred to as Panel or Round Table Discussions, at engineering society meetings have gained in popularity during the last few years and frequently high-spot a program. Where the topic selected concerns some current and widespread problem, such a session is almost certain to command a larger audience and result in more prolific discussion than the presentation of a formal paper, unless the latter involves something very unusual.

The preparation of a formal paper, if it is to represent a substantial contribution to the literature on a particular subject, requires considerable time and effort. Because of this, potential authors are often reluctant or too busy to undertake such assignments. This is especially true at present, as many program committees have discovered. Moreover, because of existing censorship rules, much that is worthwhile may be precluded.

Symposiums, on the other hand, because of their informality, usually do not require advance preparation on the part of those participating; and their very character stimulates discussion and the frank exchange of ideas and experiences. Many engineers who could not be induced to prepare a formal paper will freely express their views under such conditions.

Guided by the success of the Panel Discussion on selected power problems at the Semi-Annual Meeting in Cleveland last June, the Power Division of the A.S.M.E. is scheduling three symposiums for the Annual Meeting in December. One will deal with "Feedwater Heating Cycles and Arrangements," the second with "Boiler Water Problems," and the third, sponsored by the Heat Transfer Division, will deal with "Shell and Tube Heat Exchangers." These are timely subjects having wide application among power plants and it is anticipated that the results will fully justify the Committee's decision to hold these sessions at that time.

Questionnaires Simplified by War Production Board

It is estimated that the recent elimination or simplification of approximately 40 per cent of WPB requests for data from industry will save at least thirty million man-hours annually. This will be welcome news to many firms whose over-burdened managements have found the multiplicity of questionnaires and reports both confusing and onerous and who, in many instances, have found it necessary to add personnel to cope with the requests.

During the period of rapid expansion in the functions of the War Production Board, it was inevitable that much duplication and lack of uniformity would prevail in the numerous requests for information emanating from its various branches. Also, it developed that many of the data sought had little relation to the war production effort of the firms addressed. This uncontrolled situation finally became so serious that Chairman Nelson wisely created a Committee for Review of Data Requests, which immediately proceeded to study the forms with a view to a reduction in the number and their simplification to cover only the essential data. This has now been accomplished and all divisions and branches of WPB must not only conform to the prescribed forms but any additional questionnaires or requests for statistical information must receive approval of the Committee.

That war conditions necessitate a considerable degree of governmental regimentation is now generally and willingly accepted, but the aim should be to apply this with minimum interference to routine work that goes into the war effort. Advantage should not be taken of the situation to extend the spheres of authority of those bureaus whose functions concern economic or social reforms or regulation rather than prosecution of the war, as has been apparent in some instances.

Chairman Nelson is to be commended for having taken action as concerns WPB and it might be well to adopt a similar procedure with reference to some other government bureaus.

Man-Power in the Power Plant

Much has been said of late in government circles as to the necessity of coordinating Selective Service for the Army with the man-power needs of the country. In fact, it has been proposed that many of the older men now in military training be returned to civilian pursuits because of their physical inadaptability to the rigorous army training. This would likely include many engineers.

Inductions have taken a proportionate toll of power plant operators, particularly where deferments could not be claimed on the basis of inability to train new men for routine operation within periods specified. However, under present conditions when many plants are being taxed to capacity with little opportunity afforded for regular scheduled maintenance, ability to conduct routine operation may not be sufficient. If something goes wrong, it is the resourcefulness of the operator, gained usually through experience, that counts most in keeping the plant running or in recognizing signs leading to ultimate failure. Such background cannot be obtained in the time now allotted to training replacements.

This is a matter that demands careful consideration in any plans that are evolved from the current discussions, which so far have concerned chiefly farm and mine labor and workers in certain war industries.

A practical discussion of the various factors that influence the design and selection of boiler-feed pumps for high-pressure service. Included are the suction and discharge pressures, methods of capacity control, pump materials as affected by operating conditions and feedwater treatment, drives and lubrication. Maintenance is also discussed.

High-Pressure Boiler-Feed-Pump Practice

By L. J. DAWSON

Service Engineer, Ingersoll-Rand Company

ALTHOUGH service, experience and customer preference establish certain basic types of high-pressure boiler-feed pumps as standard, each installation may be considered as custom-tailored because of the many factors which influence the final design of the unit. The factors are numerous; to mention a few, they include suction pressure, discharge pressure, type of capacity control, materials required and auxiliary equipment.

At the outset it may be pertinent to mention the effort that has been made to improve the external appearance of boiler-feed units. Although a neat exterior does not contribute directly to the performance of the unit, the psychological effect on the operators and owners is important. A good-looking unit commands respect and is therefore more likely to be properly operated and maintained. Metal lagging covers are being used in many cases to serve a dual purpose of insulation and improved appearance. Also, much attention has been paid to oil and cooling-water piping so that the final piped job is neat and a minimum of pipe is in view. Typical units illustrating these features are shown in Fig. 1.

Influence of Suction and Discharge Pressures

In general, it may be said of a boiler-feed pump that the suction pressure determines the stuffing-box design, whereas the discharge pressure determines the casing, shell and nozzle details. New feedwater arrangements, whereby the pumps take suction from closed heaters fed by booster or tank pumps have, in many instances, increased suction pressures to higher levels ranging from 300 to 700 lb per sq in., with corresponding suction temperatures of 300 to 400 F.

With suction pressures of 200 to 600 lb per sq in., where some form of pressure reduction is necessary to provide a reasonable packing arrangement, a folded-type labyrinth has proved satisfactory (See Fig. 2). For higher suction pressures, a stepped and folded labyrinth may be used. By folding the labyrinth, the span is kept to a minimum. Clearances are 0.015 to 0.020 in., and the materials are Nitralloy or hardened stainless steel. When labyrinth leak-offs are used, the liquid pressure on the packing is in the 100 to 200 lb per sq in. range. The desirability of maintaining constant liquid pressures on the packing at all load conditions and during shutdown periods has been amply demonstrated. Fluctuating pressures result in "weaving" of the packing in the stuffing box, with attendant increase in leakage in packing life.

Where leak-off pressures vary widely because the leakage is returned to a part of the system whose pressure varies with load, some form of pressure regulation on the leak-off line should be considered. Also, sufficient liquid pressure should be maintained on the packing to prevent excessive flashing of the leak-off, as this makes it necessary for the packing to seal against steam rather than water.

For lowering the temperature of the water handled by the packing, injection-type stuffing boxes have been designed and are proving practical. In these boxes, condensate at a temperature appreciably below the feedwater temperature at the pump is injected into a lantern ring or chamber at the bottom of the stuffing box. A throttle bushing regulates the amount of condensate leaking inward to the pump. This arrangement may be used with or without labyrinth bleed-off between the pump suction and the packing (See Fig. 3).

The packing section of the stuffing box should be water-cooled when suction temperatures are over 250 F. Cool packing invites long life if other factors are favorable. Modern stuffing boxes for high-duty boiler-feed pumps are packed solid with no lantern gland in the center of the box.

When suction pressures are above 10 lb per sq in., there is sufficient leakage through the stuffing box to insure proper packing lubrication. The success of solid-packed stuffing boxes is due in no small way to new designs of the packing proper. In one manufacturer's product, the outer layer is purposely left rough to provide a multiplicity of leakage paths. In this way a predetermined amount of leakage is provided. Soft plastic or metallic foil packings are sensitive to gland pressure and are likely to seal off completely, with resultant failure due to lack of lubrication.

The influence of the pump discharge pressure on design is reflected in the casing material and construction. When pressures over 1000 lb per sq in. were called for in the latter 1920's, steel casings entered the picture, and the ground-joint parting flange was used in place of the usual fiber or asbestos gasket. This type of construction has reached a high point of perfection. Some engineers prefer barrel-type construction, and this design can be had for ratings in the same range as for split-casing pumps.

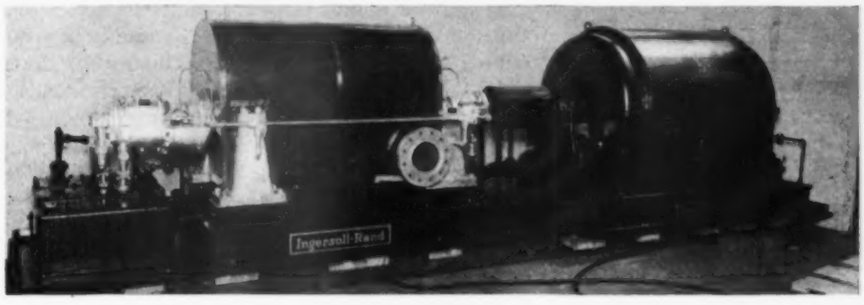
The discharge nozzle of a steel-casing pump may be designed for a bolted flange or may be beveled so it can be welded directly to the discharge line. Naturally, the bolted flange is desirable from the standpoint of casing removal; but as this is seldom necessary, the welded joint is justified for high pressures.

Capacity Control

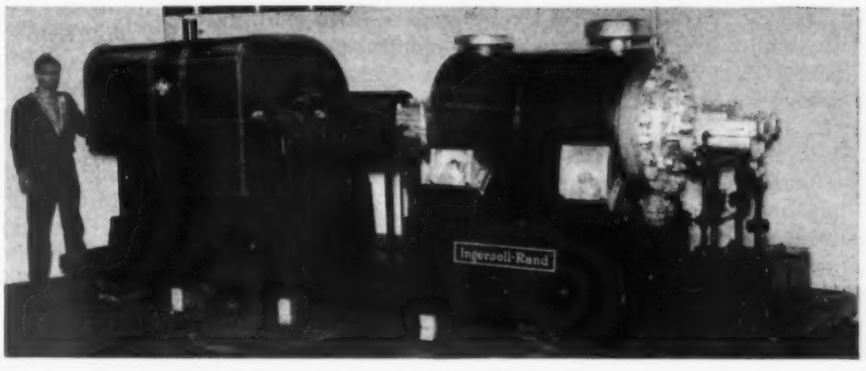
The method of capacity control for a boiler-feed pump is an inherent part of station design. Basically, the need for capacity control arises from the fact that boiler water demand is not constant; and therefore, if the water level in the boiler is to be maintained, the flow of feedwater must correspond to the demand. Regulation of feedwater flow may take place in any or all of three places: (1) at the water-level regulator, (2) at the constant-pressure regulator and (3) at the pump itself.

In simple systems, all capacity control is effected at the water-level regulator. The sloping pressure-volume characteristic curve of a centrifugal pump results in a decrease in delivery with increased discharge pressure (for constant-speed conditions). The flow to the boiler can therefore be controlled by the amount of throttling at the water-level regulator valve.

As has just been pointed out, with constant-speed operation decreased flow means increased pressure at the pump discharge and consequent increased pressure drop across the water-level regulating valve. To improve the operation of this regulator, it is often desirable to provide a constant excess pressure on the upstream side. To obtain this, a constant-pressure regulator is inserted in the feedwater header upstream of the water-level regulator. The constant-pressure regulator is controlled by the dif-



High-pressure feed pump driven by a 1250-hp motor



Turbine-driven pump—note the lagging on both pump and turbine.

Motor drive through hydraulic coupling and step-up gear

Fig. 1—Typical feed pump units representing good appearance

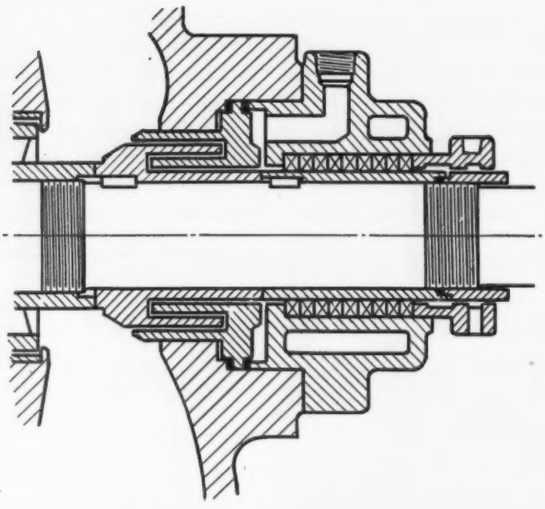


Fig. 2—Folded-type labyrinth packing used for suction pressures of 200 to 600 lb per sq in.

ferential pressure across the water-level regulator valve and acts to maintain this differential at a constant value. It is apparent that when a constant-pressure regulator is used, the control of the feedwater flow is effected in two steps: (1) by a constant-pressure throttling across the water-level regulator and (2) by a variable-pressure throttling across the constant-pressure regulator. The control has therefore passed forward in the circuit to the constant-pressure regulator.

The capacity of a constant-speed pump delivering against a fixed head may also be regulated by varying the suction pressure with a variable-speed booster pump. As the quantity delivered by the pump depends upon the total dynamic head against which the pump must operate (within the limits of the performance curve), a reduction in the total head will reflect as an increase in delivery; and conversely, an increase in total head will reduce delivery. With constant discharge pressure, increasing the suction pressure will decrease the total head which the pump must develop and thereby increase the delivery. Should a reduction in delivery be desired, the suction pressure may be reduced, thus increasing the total head to be developed by the pump and causing it to work back farther on the performance curve.

The variable-suction-pressure system of flow regulation can be used in installations where tank or booster pumps are used to deliver water to the boiler-feed pump suction. Variable-speed drive is used for these primary pumps. The effect of speed variation on capacity control will be discussed in the following paragraphs.

Where variable-speed boiler-feed-pump drivers can be incorporated in the station design, the control of flow can be precisely effected by varying the speed of the unit. Fig. 4 shows a family of performance curves for a pump running at different speeds. In general, it may be said that the capacity of a centrifugal pump varies as the first power of the speed, and the total head varies as the square of the speed.

If we draw a horizontal line on Fig. 4 at the head level corresponding to the boiler pressure (line AB), and then add to this the pipe and fittings friction at the various capacities, the resulting line AC will be the head against which the pump must operate at any given flow. The intersection of this system curve with the pump performance curve will show the flow at that condition. It can be seen that flow must stabilize at this point. If the flow increased, the head required by the system curve would exceed that which could be developed by the pump at that capacity; and conversely, if the flow decreased, the head required by the system curve would be less than that developed by the pump, so that there would be excess head to cause an increase in flow up to the intersection point on the curve.

It will be noted, however, that the series of intersections of the system curve with the family of speed curves causes a series of flow points. This means that we have only to vary the speed of the unit to regulate the capacity delivered to the system. If speed is varied in definite steps, flow will likewise vary in steps, and intermediate points must be obtained by slight throttling of the flow obtained at the next higher point. If stepless speed control is employed, no throttling control is needed. (This is not to be construed as meaning that no boiler regulating valve is needed; the friction of this valve is included in the system curve.)

Step control of speed can be obtained from slip-ring motors. For large installations, the cost of such motors and equipment becomes high, and for this reason their use is limited. Turbine drive gives stepless control and can be economically employed where the exhaust steam can be used effectively in the station heat cycle. Here again station design influences the feed-pump equipment.

In late years, hydraulic couplings have been adapted to feed-pump service, making it possible to obtain stepless speed regulation while using a constant-speed motor. In both turbine and hydraulic-coupled drivers, the speed may be automatically controlled by the discharge pressure or by the excess pressure across the boiler-regulating and/or excess-pressure valves.

Materials

Station design has a direct effect on the materials used in the construction of the boiler-feed pumps. In the early days of centrifugal boiler feeders, most pumps were

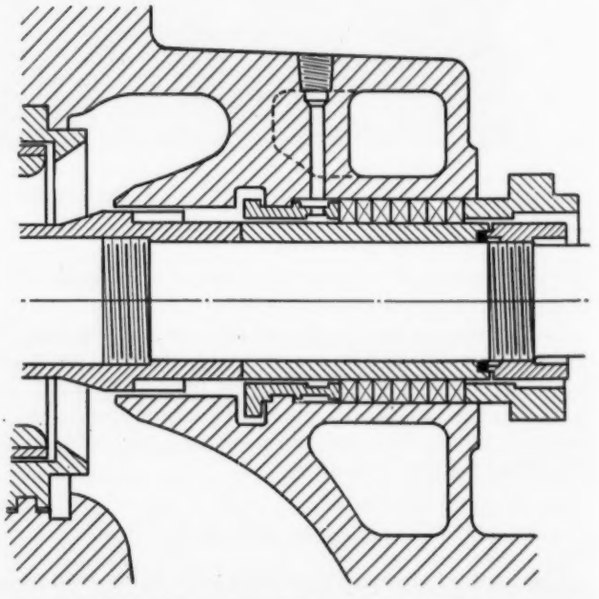


Fig. 3—Stuffing box arranged for cold condensate injection at bottom of box

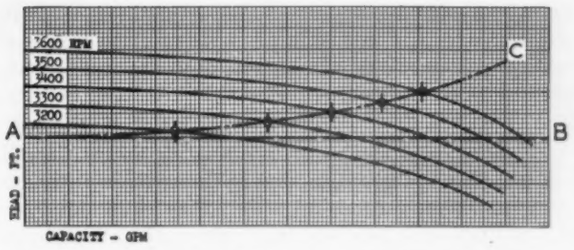


Fig. 4—Effect of variable speed on pump delivery

"regular-fitted" with bronze impellers and wearing rings and cast-iron stationary parts. As the temperatures were low and the service was not severe, the effect of the pH of the water was not noticeable. With the advent of distilled makeup and higher temperatures of feedwater in central stations, corrosion of iron and carbon steel parts became a problem. Reduction in carryover due to more efficient separator and scrubber design reduced the salts in the condensate and accentuated the attack.

The problem of attack has been solved by the liberal use of chrome-steel parts, as this metal will withstand attack throughout the pH range encountered in boiler feeding. It is well to state at this point, however, that pumps having cast-iron or carbon-steel casings require that pH be maintained above neutral, the actual value depending on the operating temperature.

Although many charts have been prepared for selection of materials from the pH value, it should be pointed out that other factors must also be considered. A study of Fig. 5 will show that temperature is of prime importance. Not only does hydrogen ion dissociation greatly increase with temperature in the range from 77 to 400 F, but the pump materials themselves are more chemically responsive to attack at elevated temperatures. The second consideration is the nature of the feedwater mixture. In general, it may be said that feedwaters composed solely of condensate and evaporated makeup are more corrosive than those containing treated makeup. The former feedwaters are unbuffered and very pure, whereas the latter will have a nominal amount of dissolved solids, and pH readings may be misleading. The unbuffered water may have a pH equal to that of the buffered water, although in the former case it is due to a minute amount of ferrous hydroxide gathered from attack on the steel parts, whereas in the latter case the pH is due to a large amount of dissolved solids. From experience it is known that the unbuffered water will attack steel until saturated with iron ions, whereas the buffered water has its hydrogen ions satisfied with salt ions and will not attack.

There are still places where all-bronze, all-iron and regular-fitted feed pumps are recommended. Pumps operating at moderate pressures and temperatures where pH of the feedwater will consistently be neutral or below may be all-bronze. For industrial plants having high makeup and using a lime and soda treatment, the pH will be high and all-iron construction is in order. Where the pH range will be closely controlled to safe limits, regular-fitted units may be used; and a saving in material cost, as compared to stainless steel, will result in a lower first cost.

The use of hardened wearing parts has increased the service life between overhauls. Records of 30,000 to 40,000 hr between overhauls are being made with regularity. Shaft sleeves of Nitralloy, case-hardened steel or hardened stainless steel permit the use of packings which would be out of the question with bronze shaft sleeves. Hardened impeller rings, casing rings, intermediate sleeves and channel ring bushings will outwear bronze or cast-iron parts by large ratios.

Auxiliaries

One accessory which is finding favor on large units is the auxiliary oil pump. This pump is usually a single-stage centrifugal unit with the pumping end submerged in the oil reservoir. The oiling system is fitted with a pressure switch so that a predetermined drop in oil pressure starts the auxiliary pump. In this way a copious supply of lubricating oil is assured if the main oil pump fails.

Electrical interlocks may be used so that the feed pump may not be started unless the auxiliary oil pump is operating. When the feed pump comes up to speed and sufficient oil pressure is developed by the main oil pump, the pressure switch cuts out the auxiliary pump.

For high-pressure pumps, a light load bypass is an absolute necessity. The minimum flow at which a pump can be safely operated is governed by the available head at the suction and its relation to the vapor pressure at the suction temperature. From this it can be seen that the station cycle and design exert an influence on the minimum flow. A certain pump may require a flow of 200 gpm with 20 ft NPSH,[1] whereas the same pump in another installation having 40 ft NPSH could get by with a minimum flow of 60 gpm.

Control of the bypass line may be either hand or automatic, the latter being preferred. With automatic control, the bypass control valve is pilot-operated from the suction flowmeter. When the flowmeter falls below the specified minimum flow, the bypass valve is opened. The valve should be of the normally open type so that failure of air supply or current protects the pump rather than endangers it. With hand control, the responsibility of opening the bypass rests with the operator, and often at loss in load, when the bypass should be opened immediately, the operator is otherwise occupied.

[1] The term "NPSH" refers to "Net Positive Head" available at the pump suction, over and above the vapor pressure.

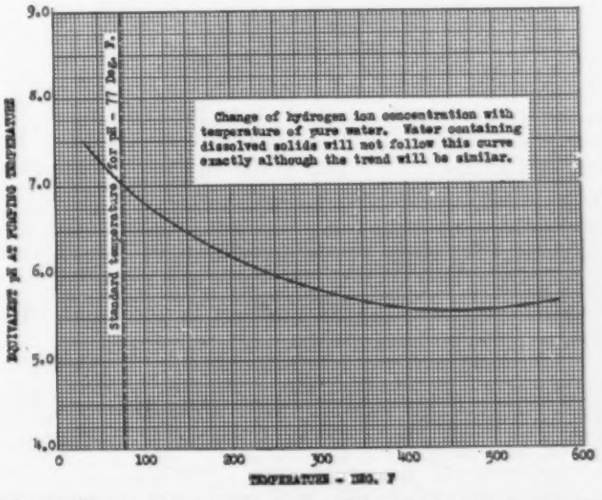


Fig. 5—Effect of temperature on hydrogen for concentration of pure water

To control the flow through the bypass line, an orifice is employed. For pressures under 1000 lb per sq in., a nipple-type orifice is satisfactory; but for higher pressures a muffled-plate orifice results in quieter operation. In either case the orifice should be engineered for the particular job.

Couplings

In the majority of cases, couplings are either gear-type or laminated-disk type. It is to be remembered that the magnetic centering force of an induction motor is not of sufficient magnitude to cause sliding of the teeth of a gear-type coupling under load. This has led to many instances of burned-out motor bearings caused by the small shoulder on the motor shaft being held against the face of the babbit bearing lining. On most motors this face is small, is not lubricated and is not capable of carrying even continuous contact, let alone any thrust load. The situation has been circumvented by the use of limited travel couplings. Laminated-disk couplings are limited in their end float by reason of design, and therefore prevent motor bearing trouble of this sort.

For large installations, spacer-type couplings are used so that shaft sleeves may be renewed without rotor removal. The spacer type is a definite improvement over the older jackshaft construction.

Pump and driver alignment must be maintained within reasonable limits if smooth operation is to be expected. Every effort should be made to have alignment within 0.003 in. horizontally, vertically and angularly when both driver and pump are at operating temperature. Units should not be dowelled until they have been operated for a short time under rated conditions so that the piping has had a chance to take a permanent set.

Maintenance

Wear in boiler-feed pumps may be classified as chemical and/or mechanical. Chemical wear is the result of attack due to improper material selection. With the advent of stainless-steel wearing parts, this phase is rapidly becoming of small importance. Mechanical wear will always be with us.

The principal parts subject to mechanical wear are the running fits, labyrinth parts, shaft sleeves and bearings. Wear of the running fits and labyrinth parts is not mechanical in the sense of actual frictional contact, except in abnormal cases; instead the wear is the result of erosive action of the flow of water at high velocity. The original clearances in these fits are 0.010 to 0.020 in., and, as a general statement, replacement need not be made until the clearance passes 0.030 to 0.040 in. The performance of the unit is the best gage of the condition of the running fits; if there is no noticeable loss of total head developed, there is no need to be concerned about the fits. It is a poor investment to open a large pump just to have a look. The cost of dismantling and reassembling is a large portion of the total cost of a complete overhaul.

Shaft sleeve life is dependent on packing conditions and the skill with which packing is handled. It is reasonable to expect, for the same sized sleeve and material, that a sleeve used for a 100-lb per sq in. stuffing box will outwear one in a 300-lb box. Packing and sleeve maintenance rises sharply with increase in pressure and temperature.

Improper packing installation or adjustment can ruin a shaft sleeve in a few minutes. A stuffing box must have continuous water lubrication, and packing operated with no leakage will burn, ruining the sleeve at the same time. Packing must be adjusted one flat of the gland nut at a time, and then a period must be allowed for the gland pressure to reach the rings in the bottom of the box. Rapid adjustment compresses the outer rings only, usually resulting in a sealing-off of the leakage and subsequent burning of the packing. Incidentally, the gland quench water should always be turned off when packing leakage is being observed.

Premature bearing wear may usually be traced to dirty oil. In pulverized coal plants there is always a certain amount of coal dust in the air and the breathing of the bearings will cause some of this to contaminate the oil. Local conditions govern the period between oil changes, and once this period is establishd, a definite schedule should be set up. On larger units centrifuging may be economically justified, while with smaller units the cost of new oil is negligible.

For best results on 3600-rpm pumps, an oil of 150 to 200 SSu at 100 F is recommended. Needless to say, the oil should be free from acids and alkalis. In most cases the oil used for the main turbine will be suitable for the boiler-feed pumps. This simplifies oil inventory.

When a large boiler-feed pump must be overhauled, it is a good investment to have a manufacturer's representative present, at least until such time as those responsible for maintenance are thoroughly familiar with the equipment. It is well to place the request for a service engineer at least a week in advance of the date actually required so that the man most familiar with the particular installation can be assigned.

Recent High-Pressure Installations

To illustrate the trend of sizes, number of stages, suction and discharge pressures and water temperatures, the following list of representative installations put in service since 1939 is offered. With the exception of the one installation noted, all are 3500- to 3600-rpm units.

Sizes and Stages	Gal per Min	Suction Pressure	Discharge Pressure	Temperature
5–8	1210	75	1740	320
5–7	1285	316	1816	400
6–6	1700	260	1665	406
5–7	1122	300	1335	350
5–7	1100	130	1600	356
5–7	680	15	1500	214
5–8	945	475	2185	340
5–7	1165	345	1755	400
5–6	1120	621	1826	452
5–7	1065	69	1650	300
5–6	1290	35	1235	281
6–6	1615	400	1625	384
5–8	1230	700	2800	340
5–7	712	400	1700	335
*2½–6	255	250	1835	212
5–7	1040	400	1735	290

* 5800 rpm.

Conclusion

In conclusion, it may be stated that the modern high-pressure boiler-feed pump is precision equipment capable of giving long periods of trouble-free operation. With an eye to the future, one may foresee a trend to higher speeds than 3600 rpm, the object, of course, being to effect a reduction in the size and cost of the unit. This trend is already evident in marine practice. Such speeds will necessitate turbine drive or speed-increaser gears if motor drive is to be used.

Prevention of Water-Side Deposits in Recirculating Cooling Systems

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and J. W. RYZNAR, Research Dept.
National Aluminate Corporation

The factors affecting the formation of insulating deposits and corrosion on the water side in recirculating cooling water systems are discussed. Studies on the effect of various treatments for scale and corrosion prevention and for control of biological growths have been made with the emphasis on elimination of calcium and magnesium deposits. The correct evaluation of all factors makes it possible to predict the behavior of any makeup water used under any specific operating conditions.

CORRECT chemical control for prevention of deposits in recirculating cooling-water systems is a difficult problem involving careful analysis of all factors or variables that are encountered with each makeup water and in each installation. This should be followed by a definite recommendation of type and quantity of chemical treatment and deconcentration control required. It is not a simple problem involving the addition of a few parts per million of a chemical "cure-all."

Difficulties with deposits, corrosion and/or biological fouling are experienced in various types of cooling equipment among which steam power plant surface condensers, refinery heat exchangers and condenser boxes, engine jackets, ammonia condensers, air-conditioning equipment, blast-furnace tuyères and open-hearth door frames are representative.

The chemical and biological compositions of the deposits may vary widely. They may consist of various combinations of calcium carbonate, magnesium hydroxide and magnesium silicate mixtures. (See Table 1 for analyses of typical recirculating cooling system deposits.) They may contain varied amounts of iron oxide, either as a corrosion product or as an adherent sludge precipitated from a makeup water high in soluble iron bicarbonates. Again, they may be composed largely of organic material from slime and algae growths or from iron bacteria such as Crenothrix, in which case the deposit may have iron oxide present along with the organic material.

The objections to any of the above-mentioned scale conditions are obvious as the deposits reduce heat transfer, increase pumping costs and cause costly shutdowns for mechanical or chemical cleanout or replacement of scaled equipment. Pitting and corrosion are not usually recognized as quickly as scale formation and frequently the metal is weakened to the point of failure. Tuberculation reduces the effective size of the pipe and its carrying capacity in the same manner as scale deposits. Slime, iron bacteria and algae form an insulating growth on heat-exchange surfaces as well as reduce carrying capacity of the pipes.

The characteristics of the makeup water and of the conditions present in the system require careful study. This fact can be appreciated more fully if it is realized that the following factors must be properly evaluated: temperature encountered in the system, velocity of flow, pH of makeup and circulating waters, calcium concentration, magnesium concentration, dissolved solids concentration, silica concentration, free CO_2, total alkalinity, dissolved oxygen, types of algae and bacteria, climatic conditions and water compositions favoring algae growth, relative chloride or sulphate content of circulating water, contamination of water in spray pond by surrounding gaseous atmosphere, efficiency of aeration in spray pond, proper application of acid or alkaline corrective treatments when used, source of water, whether chemical composition is constant or variable, and quality of water if softened.

Previous Corrective Measures

Past attempts in elimination of the deposits, corrosion or biological fouling have not always taken into account all of these factors with the result that corrective measures have not been completely successful. For example: frequently when sulphuric acid has been added for carbonate scale elimination a corrosive condition has occurred; and many times when lime, lime-soda or zeolite softening have been used either scale formation has not been completely eliminated or a corrosive condition has developed. Most attention in the past has been focused on the elimination of calcium carbonate deposits as these were most frequently encountered.

The basic principles controlling the chemical equilibrium conditions which govern the precipitation or solution of calcium carbonate have been subject to increasing amounts of study in the past few years. In 1912, Tillmans (1) proposed a calcium carbonate saturation theory for pipe protection against corrosion, but he formulated his theory in terms of free carbon dioxide

which, for waters near the saturation point of calcium carbonate, is very difficult to determine accurately. The emphasis of this and subsequent work on calcium carbonate has been for corrosion in once-through systems such as municipal water-distribution systems. Von Heyer (2) proposed the so-called "marble test," which is used by some to indicate the saturation point of water in respect to calcium carbonate. In 1935 Baylis (3) published a paper based on his experiences at Baltimore and elsewhere. He determined the calcium carbonate saturation in terms of pH and total alkalinity. This did not have general application because he took into account only these two variables. In 1936 Langelier (4) developed a general equation taking into consideration pH, calcium, total alkalinity, dissolved solids and temperature. This equation is qualitative and predicts whether the water is scale-forming or corrosive, and does not give the amount of scale or corrosion which may occur. It has been used effectively in municipal water systems.

In recirculating cooling systems where the water is aerated and concentrated by evaporation and where dilution by makeup water is constantly occurring, a continued state of changing conditions exists. It is for this reason that many of the methods adaptable to "once-through" systems have not been completely successful.

Past attempts in corrosion prevention have involved various materials producing protective film formation. These include sodium silicate, alkaline materials such as sodium carbonate, sodium hydroxide, and lime; various chromium salts; phosphates; and organic materials. Although these materials were originally used in once-through systems, their application in recirculating systems has been more successful than the materials used for control of carbonate deposits. When correct methods of control of protective film-forming chemicals are used, excellent results in the elimination of corrosion are obtained.

Corrosion may occur directly from bacterial growth because sulphate-reducing bacteria (5) produce sulphides in their life cycle, which attack iron and other metals very rapidly. Iron bacteria also cause corrosion as they consume soluble iron in their growth. These growths interfere with and destroy protective film formation on the metal surface.

In the past, emphasis on the problem of biological fouling has been centered on eliminating slime in surface condensers and general algae growth through the use of chlorine, chlorine and ammonia, chlorinated lime, copper sulphate, mercury salts, potassium permanganate and, more recently, chlorinated phenols and their sodium salts. These materials have not always given the results expected, as biological growth conditions in recirculating cooling-water systems are much more favorable than in ponds or reservoirs. These improved growth conditions are due, in part, to the increased temperature and to thin films of water exposed to the sunlight. It has been found that certain chemicals may control one type of growth and have little effect on another. For example, copper sulphate has higher killing power per unit of treatment used on blue-green algae such as Anabaena, Coelosphaerium and Oscillatoria, than on certain green algae, such as Palmella or Scenedesmus.

Treating chemicals are most effective when the water is kept within the pH limits of their maximum solubility and stability. Copper sulphate, for instance, precipitates rapidly in water of high pH in the absence of solubilizing or stabilizing agents. Increase in normal carbonate alkalinity and pH, due to biological use of free CO_2 from the water and decrease in alkalinity, and pH through growth of acid-producing bacteria, has definitely been established. Indiscriminate addition of algaecides may cause a corrosive condition in the circulating water. For example, copper sulphate hydrolyzes with the formation of sulphuric acid and liquid chlorine reacts to form hypochlorous and hydrochloric acid, which if uncontrolled, may cause damage.

As is evident from the foregoing, much work has been done by investigators on certain phases of recirculating cooling-water problems. A continuous chemical and biological research program on this problem has been maintained in this laboratory; it has been correlated and supplemented with field results; and has enabled proper evaluation of all the variables to obtain correct recommendation for results with any water and operating conditions.

The laboratory equipment used in determining the quantitative effect of the many variables on scale formation is shown diagrammatically in Fig. 1. It consists of a weighed glass coil, *A*, immersed in a constant temperature bath, *B*, which can be set for any desired temperature up to the boiling point of water, and spray cooling of the effluent water from the glass coil *C;* circulating water pump *D*, constant head devices *E*, for rate of flow control of makeup and concentrated circulating water to the weighed glass coil, and makeup water reservoir *F*. A thermometer, *G*, is for checking the temperature of effluent water from the glass coil; *H* is capillary constriction for flow control; and *I* is a valve for deconcen-

TABLE 1—ANALYSES OF TYPICAL RECIRCULATING COOLING SYSTEM DEPOSITS

	Open-Hearth Door Frame, Lab. No. 37045	Refinery Condenser Box, 1 In. Tubes, Lab. No. 33411	Ammonia Condenser, Lab. No. 35592	Engine Jacket, Lab. No. 39643	Scale from Failed Water-Cooled Tube, Lab. No. 36688	Refinery Condenser Box, Lab. No. 30807	Engine Jacket, Lab. No. 30375	Dried Slime from Heat Exchanger, Lab. No. 34072
Loss on ignition	...	6.0%	4.7%	23.1%	8.8%	8.4%	10.7%	29.8%
Silica (SiO_2)	...	0.7%	1.8%	2.2%	...	...	...	37.5%
Alumina (Al_2O_3)	2.0%	3.0%	...	...	4.6%	...	...	9.1%
Ferric oxide (Fe_2O_3)	10.0%	2.3%	14.1%	66.4%	...	2.5%	1.5%	11.5%
Calcium sulphate ($CaSO_4$)	...	14.2%	...	...	...	...	...	...
Basic calcium phosphate ($Ca_{10}(PO_4)_6(OH)_2$)	...	...	2.4%	...	...	7.1%	...	...
Magnesium phosphate ($Mg_3(PO_4)_2$)	...	...	...	...	4.1%	...	...	...
Calcium carbonate ($CaCO_3$)	78.3%	67.9%	74.9%	3.4%	44.9%	35.9%	49.9%	...
Calcium silicate ($CaSiO_3$)	3.3%	...	2.8%	1.3%	...	3.8%	...	8.0%
Magnesium carbonate ($MgCO_3$)	...	1.7%	...	...	...	...	...	...
Magnesium silicate ($MgSiO_3$)	...	3.8%	...	...	19.1%	29.9%	32.3%	3.0%
Magnesium hydroxide ($Mg(OH)_2$)	5.8%	...	...	...	18.3%	11.2%	5.4%	...
Ferric phosphate ($FePO_4$)	...	...	...	4.7%	...	...	...	...
Oil	...	...	...	...	...	...	0.4%	...

tration. The laboratory set-up of this equipment is shown in Fig. 2. Examples of clean and scaled coils are shown in Fig. 3.

Test runs were first made with the equipment to ascertain the quantitative reproducibility of results in scale formation on the glass coils. It was found that results could be easily duplicated.

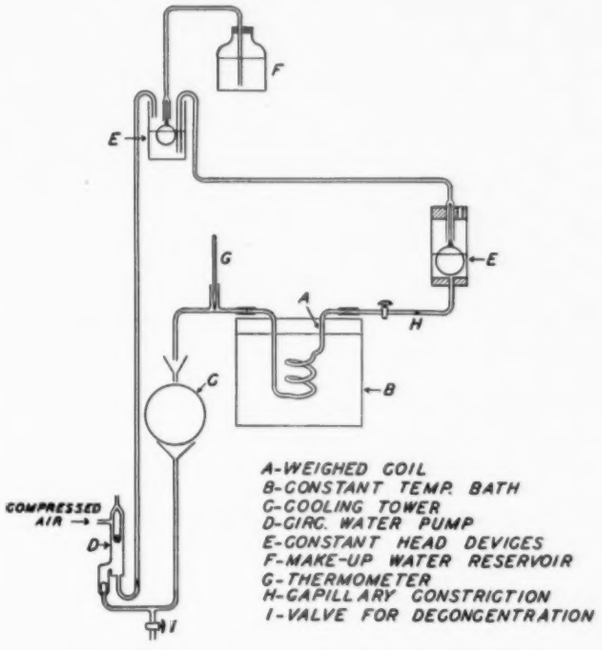


Fig. 1—Diagram of laboratory equipment used

A series of tests was made using raw makeup water of the following composition:

Total hardness in terms of $CaCO_3$	28.0 gpg
Calcium hardness in terms of $CaCO_3$	19.0 gpg
Phenolphthalein alkalinity in terms of $CaCO_3$	0.0 gpg
Total alkalinity in terms of $CaCO_3$	20.4 gpg
Total chlorides in terms of NaCl	0.4 gpg
Total sulphates in terms of Na_2SO_4	15.0 gpg
pH	7.6 gpg

Various treatments and dosages were used. Fig. 4 shows a comparison of scale formation occurring through the use of untreated raw water, water treated with organic material, water treated with supercooled septaphosphate and water treated with blended organic-phosphate material. All treatments were at a dosage of 1.0 grain per gallon of makeup water.

The blended organic-phosphate material produced the least deposit on the glass coils and allowed higher concentration ratio to be carried in the circulating water before a serious scale-forming condition developed.

A large number of organic materials were tested alone and blended with various amounts of inorganic salts. Tannins, lignins, lignin derivatives and starches of many types were tested and a few of these materials were found to have a marked effect in eliminating scale deposits on the coils. Blends of lignin and lignin-derivative organic materials with phosphate gave the best all-round results with this water, but, depending on the composition of other waters tested, the quantities and types of organic and phosphate varied to produce the best results. In the presence of these treatments, any crystals formed were colored and greatly distorted.

The adsorption of various materials on crystal faces and the resulting supersaturation obtained have been noticed and studied by various men.

Marc (6) found, for example, that with sufficient concentration of dye, potassium sulphate solution became greatly supersaturated before crystals appeared. Likewise acid dyes would cause thallous chloride solution to become supersaturated several hundred per cent.

Saylor (7) said that when an ion is strongly adsorbed on calcite, it will cause the calcite to supersaturate because the adsorption dirties the surface of each new calcite nucleus as soon as it appears and so keeps it from growing.

Reitemeier and Buehrer (8) studied the effect of adsorption of phosphates on calcium carbonate precipitation from ammoniacal solutions.

Other investigators in this field have been Kohlschütter and Egg (9), France (10) and his co-workers.

The effectiveness of blended organic-phosphate treatments in preventing deposits is due to inhibition of crystal growth up to a certain point of supersaturation, adsorption of treatment on crystal faces, crystal distortion caused by adsorption and proper conditioning of crystals that are formed to give a non-adherent free-flowing sludge.

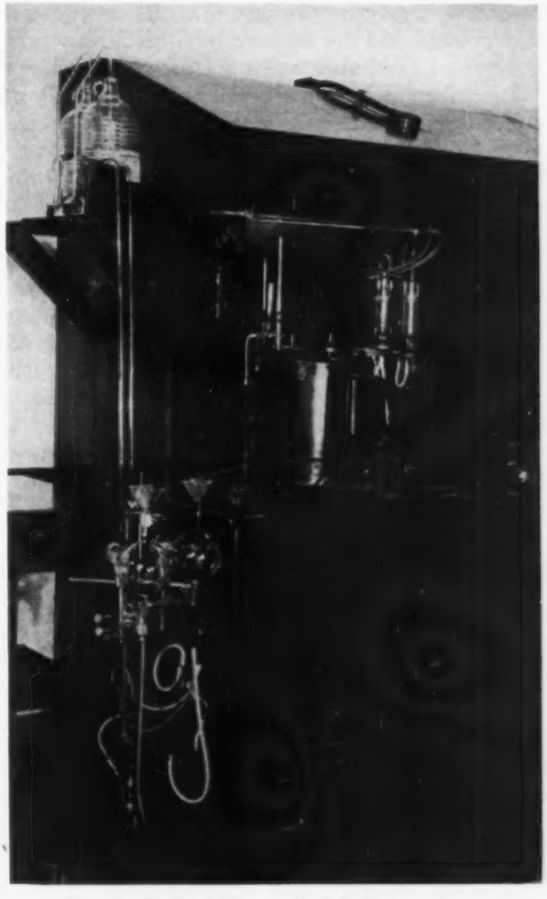


Fig. 2—Laboratory recirculating system

In the absence of any nuclei or minute crystals there is no crystallization or growth of crystals from a supersaturated solution. In the presence of organic-phosphate inhibitors a similar condition of non-crystallization is present up to a certain point in the supersatura-

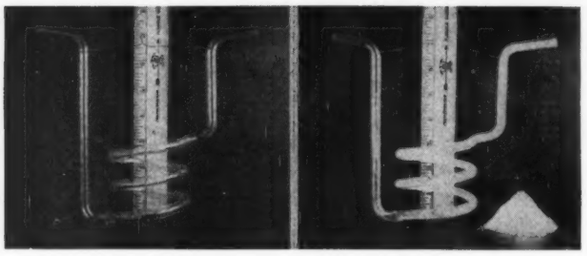


Fig. 3—Clean and scaled coils

tion. This point will vary, depending on the treatment materials used, and obviously the better the treatment the greater can be the amount of supersaturation without crystallization. Above this point, crystallization will proceed irrespective of the presence of the inhibitor, but even here the presence of a treatment that is strongly adsorbed on the crystalline phase will tend to peptize the crystals or prevent crystal growth. This inhibits growth of a great many crystals, but a few are formed and these are much larger and are deformed in structure. In the absence of treatment, the crystals are small with no marked distortion.

That the organic-phosphate treatments are strongly adsorbed is known by the fact that the crystals become highly colored and are distorted. This is shown in Fig. 5, *a*, *b*, *c* and *d*. Exhibit *a* shows the small fine crystals obtained when no inhibitor is present. In *b* is shown the effect of organic material alone. This shows increase in size and distortion. The crystals themselves are colored. Some organic materials give smaller crystals, but these are also generally colored and distorted. Exhibits *c* and *d* show the effect of the combination of phosphate and organic materials on crystal distortion and growth. They also show how a proper choice of organic-phosphate treatment can give crystals having widely different characteristics. The adherence between crystals can be controlled to form porous, loosely adherent deposits easily removed. This is in contrast to the fine, hard, dense scales formed in absence of any modifying treatment. This point is of importance in treating recirculating cooling waters because water composition or

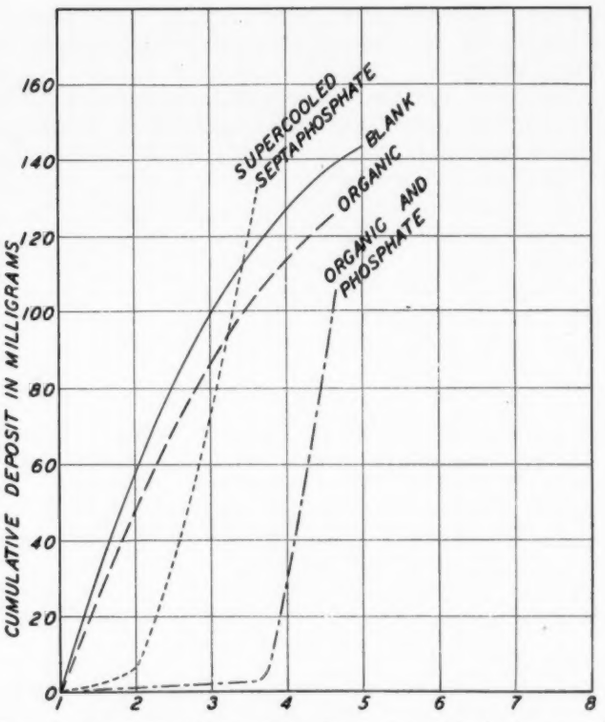


Fig. 4—Concentration ratio between circulating and makeup water

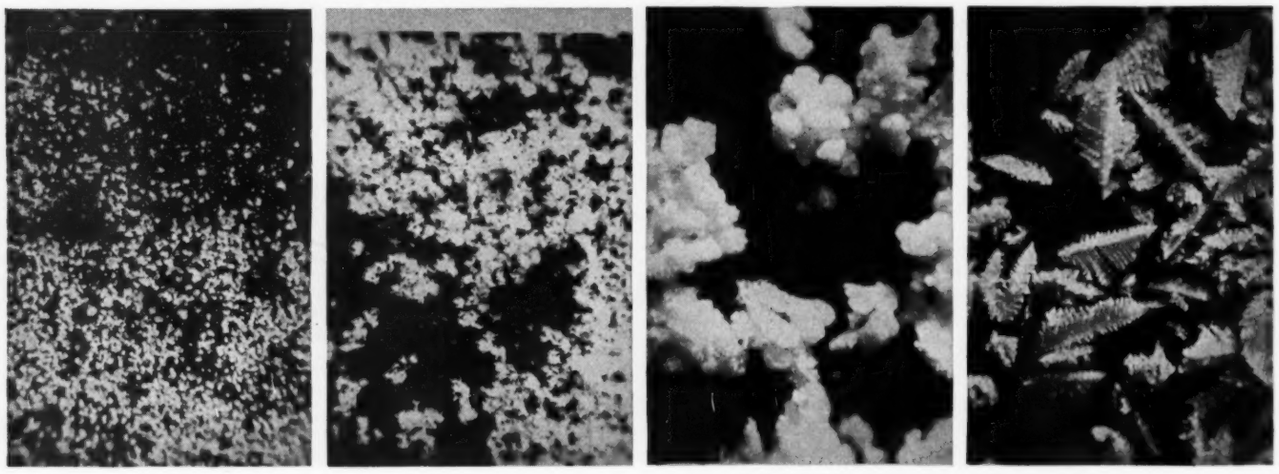
water scarcity may not always permit the operation of the system in a non-scaling range.

A series of tests was made on a raw makeup water having a high soluble iron content as shown in the following analysis:

ANALYSIS No. 35702

Total hardness in terms of $CaCO_3$	17.2 gpg
Calcium hardness in terms of $CaCO_3$	12.8 gpg
Magnesium hardness in terms of $CaCO_3$	4.4 gpg
Phenolphthalein alkalinity in terms of $CaCO_3$	0.0 gpg
Total alkalinity in terms of $CaCO_3$	13.6 gpg
Total chlorides in terms of NaCl	2.6 gpg
Total sulphates in terms of Na_2SO_4	14.5 gpg
Iron	10.5 ppm
pH	7.0 ppm

It was found that special blends of organic-phosphate treatment were necessary to produce best results with



a No inhibitor

b Organic material alone

c *d* Organic materials and phosphate

Fig. 5—Effect of stabilizing treatments on crystal growth

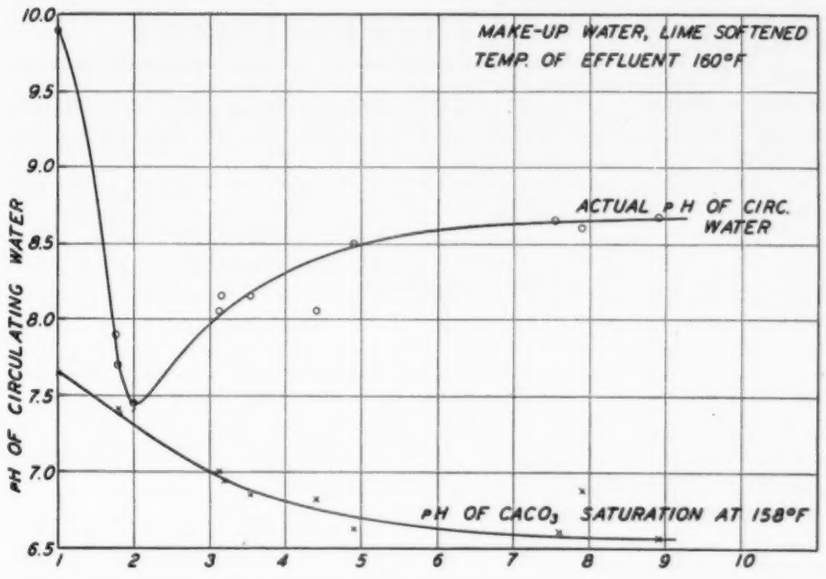


Fig. 6—Concentration ratio between makeup and circulating water

this type of water. Soluble iron in the makeup water reacts with and precipitates the stabilizing treatment under the pH and aeration conditions commonly found in the circulating water system, causing a deficiency for scale prevention; so the treatment type and dosage must be based on the iron content of the makeup water as well as the pH and aeration of the circulating water.

pH an Important Factor

Among the important variables in recirculating systems is the pH of the water. The pH change occurring in the water when it is brought into the system as makeup and concentrated in the circulating water is the sum of a large number of variables. These include composition of the makeup water; temperature maintained in the equipment cooled by the circulating water; concentration ratio being maintained in the circulating water system; efficiency of aeration and possibility of contamination from the gaseous atmosphere around the spray pond or tower; quantity of calcium carbonate (solid phase) in the system; proper application of acid or alkaline corrective treatments when used; types of algae and bacteria and climatic and water conditions favoring their growth. The CO_2 liberation or absorption by the recirculating water in its passage through the spray pond or tower, and the concentration ratio being carried in the circulating water are two of the main factors governing the pH change. Makeup waters containing sodium bicarbonate in excess of hardness produce higher pH conditions in recirculating systems than waters having sulphate hardness present.

Table 2 represents laboratory analyses of highly concentrated plant circulating water with high pH when the makeup water contains sodium bicarbonate, and Table 3 shows laboratory analyses of plant circulating water of lower pH when the makeup water contains sulphate hardness.

TABLE 2

	Analysis No. 41122 Makeup Water	Analysis No. 41123 Circulating Water
Total hardness in terms of $CaCO_3$	0.3 gpg	0.0 gpg
Total alkalinity in terms of $CaCO_3$	25.7 gpg	270.0 gpg
Total chlorides in terms of $CaCO_3$	3.6 gpg	43.5 gpg
Total sulphates in terms of $CaCO_3$	1.0 gpg	10.9 gpg
pH	9.3	10.0

TABLE 3

	Analysis No. 39626 Makeup Water	Analysis No. 39625 Circulating Water
Total hardness in terms of $CaCO_3$	9.9 gpg	21.2 gpg
Calcium hardness in terms of $CaCO_3$	6.7 gpg	14.4 gpg
Magnesium hardness in terms of $CaCO_3$	3.2 gpg	6.8 gpg
Phenolphthalein alkalinity in terms of $CaCO_3$	0.3 gpg	0.0 gpg
Total alkalinity in terms of $CaCO_3$	0.9 gpg	2.1 gpg
Total chlorides in terms of NaCl	15.3 gpg	27.5 gpg
Total sulphates in terms of Na_2SO_4	7.4 gpg	17.2 gpg
pH	8.8	7.8

Fig. 6 shows an example of pH change which occurred in a test run with the laboratory equipment at various concentration ratios, using a makeup water of the following composition:

Total hardness in terms of $CaCO_3$	7.2 gpg
Calcium hardness in terms of $CaCO_3$	6.2 gpg
Magnesium hardness in terms of $CaCO_3$	1.0 gpg
Phenolphthalein alkalinity in terms of $CaCO_3$	1.3 gpg
Total alkalinity in terms of $CaCO_3$	1.8 gpg
Total chlorides in terms of NaCl	0.9 gpg
Total sulphates alkalinity in terms of Na_2SO_4	12.0 gpg
pH	9.9

The pH tests of circulating water in the laboratory experiment checked very closely with results in the field on this water.

TABLE 4

	I Analysis No. 31231 Well Water Makeup	II Analysis No. 36655 Circulating Water	III Analysis No. 40955 City Water	IV Analysis No. 40956 Lime-Aluminate Softened Water Makeup	V Analysis No. 40957 Circulating Water
Total hardness in terms of $CaCO_3$	54.0 gpg	52.0 gpg	5.4 gpg	31.6 gpg	36.4 gpg
Calcium hardness in terms of $CaCO_3$	35.0 gpg	23.0 gpg	2.0 gpg	22.8 gpg	21.2 gpg
Magnesium hardness in terms of $CaCO_3$	19.0 gpg	29.0 gpg	3.4 gpg	8.8 gpg	15.2 gpg
Phenolphthalein alkalinity in terms of $CaCO_3$	0.0 gpg	1.7 gpg	1.2 gpg	0.2 gpg	0.0 gpg
Total alkalinity in terms of $CaCO_3$	23.4 gpg	24.3 gpg	4.9 gpg	1.2 gpg	10.8 gpg
Total chlorides in terms of NaCl	5.2 gpg	7.3 gpg	2.1 gpg	7.8 gpg	12.3 gpg
Total sulphates in terms of Na_2SO_4	43.5 gpg	45.0 gpg	40.5 gpg	46.5 gpg	201.0 gpg
pH	6.9	8.6	9.2	10.3	7.9

In Table 4, Column II, is a laboratory analysis of plant circulating water pH when using raw well water for makeup; and Column V shows circulating water pH using makeup blended from lime-sodium aluminate softened and city tap water. Scale elimination and corrosion prevention have been obtained with organic-phosphate treatment of the blended makeup water.

Conclusions

In general, two methods have been followed in corrosion prevention in recirculating cooling systems, namely, deaeration of the water to remove the oxygen and application of chemicals to produce an impervious stain or film on the surface of the metal in contact with the water. In our laboratory experiments, protection by stain or film greatly improved when the pH of the circulating water was within correct limits for calcium carbonate supersaturation and blended organic-phosphates were used for elimination of scale.

Growth of sulphate-reducing bacteria has been recognized to play an important part in corrosion occurrence and the elimination of these bacteria by chlorophenate derivatives has economically solved many corrosion problems of this type.

Silt or other suspended material in the circulating water may be held by biological growths and indirectly cause adhering deposits on heat exchange surfaces. Slime and algae absorb treatment which has been added for scale prevention and systems containing these growths require heavier stabilizing treatment dosages for best results in scale prevention. Slime and algae treatments which are compatible with scale prevention treatments have been developed.

The factors affecting scale deposition, corrosion and biological growth in recirculating systems have been studied and they can be evaluated properly. The behavior of any makeup water for any operating conditions can be predicted accurately and a recommendation for the proper treatment and control can be given.

Acknowledgment

Many helpful suggestions in the recirculating cooling-water research problem were contributed by J. A. Holmes, Director of Service, and Dr. P. G. Bird, Research Director, National Aluminate Corporation. The unique circulating water pump used was devised and constructed by Dr. A. O. Walker, Chief Chemist, National Aluminate Corporation.

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Facts and Figures

The weight of boiling water at 2000 lb pressure is slightly less than two-thirds that at atmospheric pressure for the same volume.

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In ten war plants now under construction 12,000 tons of copper are being saved through the use of silver for electric conductors.

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High-volatile bituminous coals generally have a lower grindability index than those of low volatile. Hence, when changing from a high-volatile to a low-volatile coal, greater pulverizing capacity and fineness usually result, other things being equal.

•

Steam plants in Argentina are required to burn a certain proportion of grain and corn as fuel. This is because of the present coal and oil scarcity and the surplus of grain and corn that has resulted from the shipping situation and loss of foreign markets.

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The earliest patent in this country relating to colloidal fuel (pulverized coal suspended in fuel oil) was taken out by H. R. Smith and H. M. Munsell in 1879. Since then, many such patents have been filed both here and abroad.

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If fuel-burning central stations were operating today at the average efficiency that prevailed during World War I, they would consume this year additional fuel equivalent to approximately 110 million tons of coal. Thus twenty-five years advance in power plant practice can be considered as a distinct contribution to the war effort, through saving in mine labor and transportation; also labor within the plants themselves.

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In order to get the maximum out of materials now contained in electric power equipment, capacities are being stepped up beyond the nameplate ratings of many generators, and one of the leading manufacturers of electric motors urges that motors be overloaded as much as 25 per cent when open and subject to normal atmospheric temperature, or from 10 to 15 per cent when enclosed. This departure from former conservative practice has become necessary because of the critical materials situation.

•

The question has been asked as to why it is necessary in marine practice to desuperheat auxiliary steam, whereas in large stationary plants the auxiliaries usually operate on superheated steam. The reason is that steam-driven auxiliaries in the stationary plants are usually larger and the turbines are designed to run on steam at the pressure and temperature used for the main units; whereas in marine work such auxiliary units are smaller and are not designed for high steam temperature. Also, saturated steam is generally employed for the backing turbine.

A Peculiar Phenomenon of Flue-Gas Analysis

By J. R. DARNELL

SEVERAL years ago when making a study of a large number of flue gas analyses in a plant where I had charge of fuel conservation, I noted certain peculiarities in the figures with reference to the relationship of CO_2 to the total of CO_2 and O_2. No CO was recorded in any of the analyses in question. The following are examples of some of the figures:

Per cent CO_2	Per cent, total (CO_2 plus O_2)
13.5	18.6
12.5	18.7
11.1	19.1
10.2	19.5

From an ultimate analysis of the coal, the maximum CO_2 with no excess air was figured at 18.45 per cent. In each of the above analyses, the total of CO_2 and O_2 is greater than the maximum theoretical CO_2. In a number of cases, however, the total was exactly equal to maximum CO_2 even with changes in the percentage of CO_2 in the sample. In other cases the increase of the total over the theoretical CO_2 value was greater than could be explained by any allowance for hydrogen and sulphur in the fuel. In some instances, although I never encountered any, there may be a lower total than the maximum CO_2. Such condition might indicate a higher ratio of hydrogen to carbon than that which is shown by the fuel analysis.

At that time I had never seen nor heard a satisfactory explanation of this phenomenon. I wrote to ten leading combustion engineers for their opinions and was surprised to find that most of them seemed to regard the problem as very elementary, saying it could be explained by simple chemistry. Engineer X wrote:

"With C and H_2 remaining constant and with perfect combustion, the ratio of CO_2 to H_2O in the flue gas will remain constant. With increasing O_2 the sum of CO_2 and O_2 will, of course, also increase over that with no excess air."

This was the burden of the answers of most of the others but they did not appear to explain the peculiarity which I had observed.

Engineer X, however, did add the following:

"The differences, however, are frequently greater than are explainable by the above. This was once investigated by Professor Breckinridge without conclusive results. Possible reasons are:

"1. Smouldering unburned combustible in the back passes.

"2. Higher hydrocarbons undetected by analysis.

"3. Presence of CO_2 forming compounds in the ash.

"4. Formation and subsequent combustion of traces of blue water gas from moisture."

In the first part of his letter, Engineer Y gave almost the same elementary explanation as Mr. X had first given, stating that the hydrogen removes some of the oxygen, forming H_2O, which is condensed and which does not show in the analysis. In his next paragraph Mr. Y offered an explanation which may have the same underlying reasoning as the first point mentioned in Mr. X's answer:

"In a fuel bed the coal on burning does, of course, not remain in the form as originally fired but becomes largely coke, plus a little fresh coal from which the volatile immediately starts to distill when heated. Therefore, you can obtain conditions which are between burning coal and burning C. The sum of CO_2 and O_2 will be between 20.9 and that figured from the ultimate analysis."

From Engineer Z an answer was received which may be based on the same reasoning as point 3 in Mr. X's answer, although I am not certain whether Mr. X did not intend to say "formed from" instead of "forming." Mr. Z said:

"As regards the increasing trend of the sum of the $CO_2 + O_2$, as the CO_2 content decreases, I have never been able to obtain a perfectly satisfactory explanation of this observed trend, but believe that it may be due in part to inaccuracy of the ordinary Orsat analysis, especially as regards the CO determination and possibly due to the presence in varying degree of other gases not shown by the Orsat determinations.

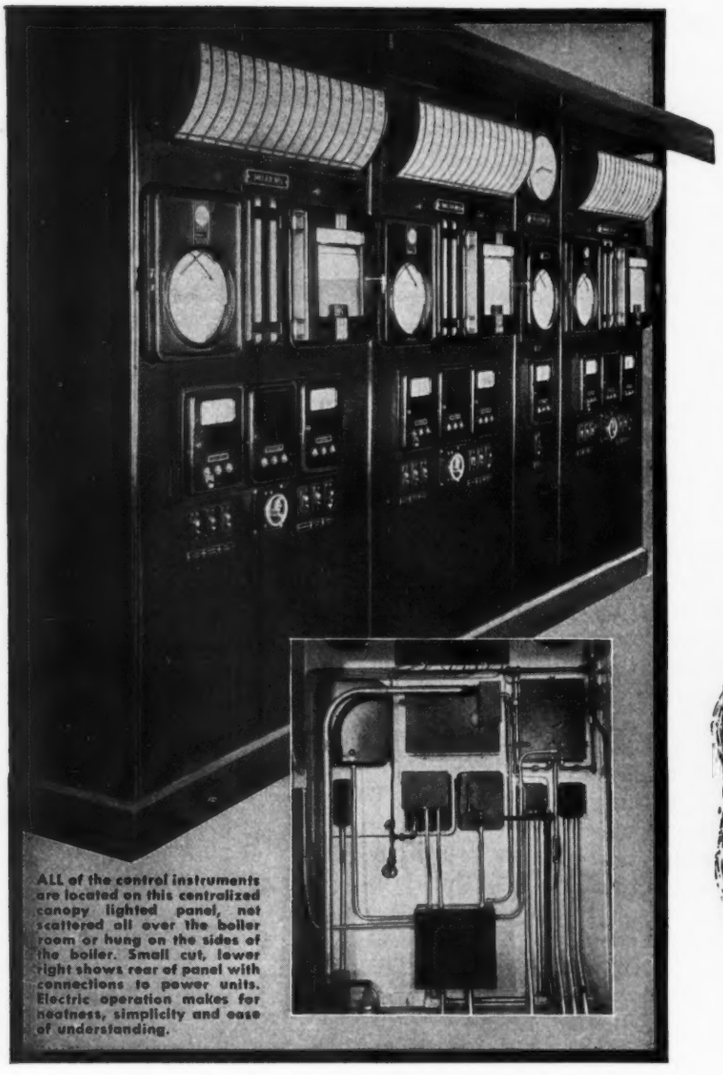
"These same factors may, to some extent, account for the registering of CO_2 content in excess of the theoretical under certain conditions, but there is another factor which doubtless contributes to this result with certain coals and that is the inert matter in the volatile driven off as CO_2. This is particularly true of coals like the Illinois varieties where appreciable amounts of carbonates are present which break down in the furnace."

It is interesting to note that the three engineers who gave answers which, at least, appear plausible, were formerly connected with the Fuels Section of the United States Bureau of Mines and had been intimately associated with combustion problems involving studies of flue gas analyses.

A further substantiation of the theories advanced by these engineers appeared in an article entitled "Flue Gas Computations" by A. A. Bato, which was printed in *Mechanical Engineering*, Vol. 48, April 1926. In this the author says:

"During moments of irregular fuel supply, the most surprising analysis is often obtained. For instance, in the case of an overfeed stoker, if a great amount of green fuel is suddenly pushed over the incandescent fuel bed, or an avalanche takes place, the result obtained from the diagram for CO may even be negative. The reason for it is the fact that when coking some kinds of coal the first products of distillation contain a high percentage of CO_2, which mixes with the flue gas without a corresponding amount of nitrogen, as it is not a product of combustion with air, and results in too high values for $CO_2 + O_2$. On the other hand, if the fire is banked for a long time, the fuel on the grate will contain less hydrogen in proportion to the carbon than the green fuel, as most of this gas was distilled with the volatile part of the fuel."

[This condition is quite general. If a plot were to be made with excess air as abscissa and both CO_2 and O_2 as ordinates, the CO_2 curve, beginning at a value corresponding to the theoretical, would steadily decrease with increased excess air, whereas the O_2 curve beginning at zero would show the opposite characteristic. If points are taken on both curves for given percentages of excess air, and a third curve plotted for their sum, this last curve, beginning at a value corresponding to the theoretical maximum CO_2 for the given fuel, will slope upward with increase in excess air, and if extended to approach infinity the sum of CO_2 plus O will approach 21 per cent, the approximate oxygen content in air. The slope will depend upon the ratio of carbon burned to that of the hydrogen. An exception will be noted in the case of blast furnace gas for which the curve will slope downward. With pure carbon, if completely burned, the plot would be a straight horizontal line.—EDITOR.]



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FIRING COAL AND NATURAL GAS on Stoker-Fired Units

By H. L. CRAIN
Kansas City Power & Light Co.

The following excerpts from a paper presented at the Joint A.S.M.E.-A.I.M.E. Fuels Conference in St. Louis, Sept. 30 to Oct. 1, relate experience in burning natural gas, to supplement coal, over chain-grate stokers serving five boilers in the Grand Avenue Station at Kansas City. The principal reasons for this combination were to increase dependable boiler capacity when burning inferior coal and to take advantage of available dump gas at an attractive price.

THE availability of natural gas for purchase on a dump contract at an attractive price was the basic reason for installation of gas-burning equipment in 1937, under three boilers at the Grand Avenue Station of the Kansas City Power & Light Company. Desirable features, other than fuel costs, were considered. It was anticipated that the maximum boiler capacity, with existing draft equipment, could be increased and that dependable boiler capacity could also be increased at times when inferior grades of coal were burned. It was not planned to replace coal with natural-gas fuel but to supplement coal firing with gas by burning both fuels simultaneously.

The installation was to be made on C-E Ladd-type steam-generating units of 225,000 lb per hr capacity each, which had been designed to burn $1^1/_4$-in. Missouri coal screenings on forced-draft chain-grate stokers of 528 sq ft area, using preheated air of 350 F.

Coal was supplied from strip-pit mines in the west central part of Missouri and contained approximately 11 per cent moisture, 17 per cent ash, 3 per cent sulphur, 31 per cent volatile, 41 per cent fixed carbon, and 10,500 Btu per lb as received from the mines. No trouble was experienced when burning coal of this quality. However, inferior grades of coal were received at times, and on these occasions clinker trouble was experienced. Huge slabs of a heavy fused mass of refuse would be conveyed to the ash pits, resulting in decreased ratings, higher ash-pit loss and lowered boiler efficiency. It was impossible to clear up the trouble except by reducing the boiler rating further and running the coked fuel bed into the pits.

Combustion with this poorer grade of coal also resulted in dirtier heat-absorbing surfaces and increased preheated-air temperature to the stokers, which in turn aggravated the coking process. While it was possible to use preheated air of 400 to 450 F with the better coal, at times the maximum usable air temperature to prevent coking with the inferior grades did not exceed 300 to 350 F. For better control of air temperature, air bypasses were installed around the air preheaters, and some time later water sprays, discharging onto the stoker just ahead of the coal hoppers, were installed to cool the grates. The combination of air bypasses and water sprays reduced the coking difficulties with no apparent detrimental effect on the stokers but at the expense of stack temperature.

The proposed use of gas fuel was not expected to result in increased capacities and non-coking conditions at all times, as gas was to be purchased on a dump basis and the station was subject to having the gas supply cut off at an hour's notice. Also, there was the possibility in extremely cold weather that gas would not be available for a period of 2 months and at a time when it would be very desirable. However, its use was expected to result in increased dependable capacities, when it was available.

The first installation consisted of four sets of three burners each, arranged in line across the rear boiler wall, at a height of approximately 11 ft above the stoker and just above the throat of the combustion chamber (see Fig. 1). The burners were of the fishtail type, set between the waterwall tubes and directed upward at an angle of $22^1/_2$ deg to the horizontal. There was no provision for premixing of gas and air for combustion ahead of the burners, and the air supply was through sets of stainless-steel louvers surrounding each group of burners. There was a divided-duct arrangement for each group of burners, consisting of one large and one small area with manual damper control for air regulation.

In operation, the direction of the burners and louvers resulted in too high a temperature in the superheater

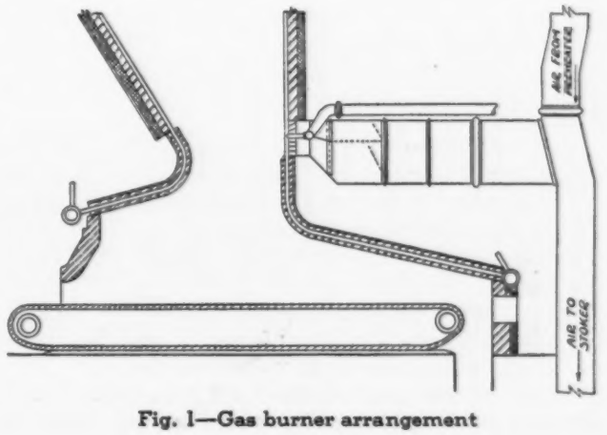

Fig. 1—Gas burner arrangement

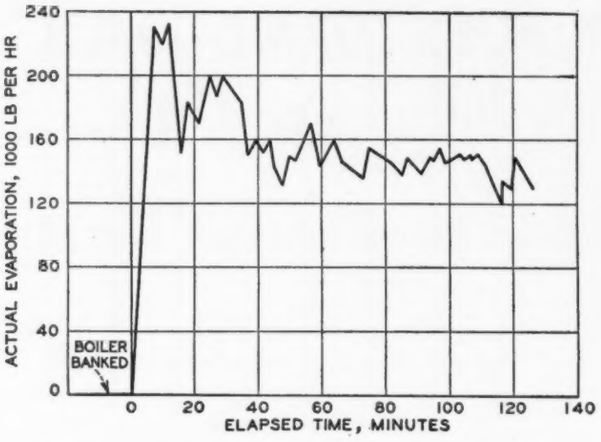

Fig. 2—Rating pick-up from banked boiler with gas

zone, and after numerous trial settings, the burner tips were finally rotated 180 deg to a downward direction, the air louvers being set to direct the air above the burners downward and that below the burners horizontally. This resulted in satisfactory furnace conditions.

Some difficulty was also experienced in gas regulation at low gas flows, which was attributed to large gas-burner area. Consequently in the installation in the second boiler the area was reduced by replacing the twelve 3-in. burners with sixty 1-in. size, giving a reduction in burner area of 45 per cent. This was accomplished by replacing each large burner with a vertical header containing five of the smaller burners. In the original installation, the center burner of each group was blanked off with a corresponding reduction in burner area of $33^1/_3$ per cent. Since both methods improved gas regulation with no distinct advantage of one over the other, the latter method was used in the third boiler. In any of the three boilers, operation may be with one to four sets of burners, but normal operation is with two sets at low gas flows and four sets at high gas flows.

The extension of gas burning to two additional boilers was made in 1941. These installations were somewhat different from the one originally made, because of construction difficulties and available space. In one boiler, 24 burners were arranged in two groups of 12. There were four horizontal rows of three burners each per group. The two upper rows and the two lower rows were controlled separately, thus allowing the use of either 12 or 24 burners, depending upon the requirements. In the other boiler, the arrangement was with 20 burners in two groups of 10, with two rows of 5 each per group. Upper and lower rows were likewise controlled separately All burners in both boilers were of the fishtail type.

In all boilers the gas flow is controlled by pressure-balanced regulating valves. Burner pressures range up to 25 in. of water on the first three installations and up to 60 in. on the latter two which have less burner area than the former. Gas-main pressures are normally from 10 to 15 lb gage.

The maximum gas consumption on any one stoker-fired boiler has been 256,000 cu ft per hr, and the maximum boiler rating obtained, 255,000 lb per hr. This represents 75 per cent of the total fuel requirement being supplied by gas and 25 per cent by coal, which is the minimum quantity of coal burned on the stoker when using gas. The average use of gas on stoker-fired boilers has been 25 to 30 per cent of the total fuel. When the amount of gas is limited, it is used preferably on swing boilers with coal as the base fuel, since swinging with gas gives the faster response to load fluctuations.

The combined firing of coal and gas is satisfactory in all respects. From a load-handling standpoint it is very flexible and convenient. When gas is available, dependable boiler capacities are increased, and maximum capacities with existing draft equipment are increased 25,000 to 35,000 lb per hr per boiler. The use of gas helps ignition of poor-quality coal and relieves coking troubles by reducing the rate of coal burning and by reducing air temperature to the stoker. The lower air temperature is a result of cleaner steam- and water-heating surfaces. The use of gas has eliminated the necessity of using the air bypasses on the air preheaters. Another favorable item is the reduced time for bringing a boiler on the line in an emergency (see Fig. 2). Pick-up with gas, from a banked boiler to 225,000 lb per hr, is approximately 7 min.

Results Attained With Gas Fuel

The burning of 1,350,000,000 cu ft of gas fuel on stoker-fired units in 1941, or 25 per cent of the total fuel requirements at Grand Avenue Station, resulted in the following:

1. No change in average monthly efficiency over burning coal alone.
2. No change in banking losses.
3. Comparable base-fuel costs.
4. Reduced fuel-handling labor costs.
5. Reduced maintenance on fuel-handling and burning equipment.
6. Reduced power consumption on fuel-handling and burning equipment.
7. Increased steam temperature.

There was no reduction in average monthly boiler-operating efficiency, as would normally be expected when burning gas, due to increased hydrogen and moisture losses. However, calculated test efficiencies with boilers thoroughly cleaned before tests do show a decrease in boiler efficiency with the use of gas. The fact that no reduction in operating efficiency was experienced over periods of time is attributed to the fact that the use of gas resulted in cleaner boilers and better heat transfer as well as lowered ash-pit losses, which offset increased hydrogen losses.

At Grand Avenue Station, the practice of holding boilers on a bank with gas fuel is not followed as it is desirable to maintain a bed of coal on the stokers, even during banking periods. However, results obtained at Northeast Station, where gas is used for banking on strictly gas-fired boilers, indicate that a considerable saving can be made in this manner.

One unexpected result of the gas installation was increased steam temperature. In spite of the reduced amount of flue gas obtained by burning gas, the steam temperature increased approximately 15 F at a normal rating of 150,000 lb per hr. This increased steam temperature is attributed to the location of the gas burners, which were high enough in the furnace to increase the gas temperature in the superheater zone.

Solubility of Salts in High-Pressure Steam

The tests reported here in abstract were made at pressures above 2000 lb. The results tended to substantiate the solubility theory that the saturated steam at such pressures retains small amounts of boiler water salts in solution, and as the pressure and temperature recede in passage of the steam through the turbine, the solubility decreases and the salts are deposited selectively on turbine blades.

IN A paper before the Third Annual Water Power Conference, sponsored by the Engineers' Society of Western Pennsylvania at Pittsburgh, November 9 to 10, Professor **F. G. Straub,** reported on recent investigations on the solubility of salts in steam at high pressures as conducted at the University of Illinois Experiment Station under a cooperative arrangement with the Utilities Research Commission, Inc.

Professor Straub prefaced his report by a review of the several theories that have been advanced to explain the relationship between the salts in boiler water and the deposits on turbine blades. These, briefly, are as follows:

1. The widely accepted "Carryover" theory is based on the assumption that boiler water containing salts in solution is entrained with the steam.

2. The "Evaporation" theory assumes that salts present in the boiler water are carried into the steam due to their partial vapor pressure.

3. The "Solubility" theory considers that steam at high pressure does not behave as a perfect gas, but has the property of dissolving the salts present in the boiler water. As the pressure and temperature through the turbine decreases, a point is reached where the steam becomes supersaturated with respect to the salts and the latter crystallize out on the turbine blades. Since various salts have different solubilities, they will separate out in different stages of the turbine.

4. The "Caustic" theory assumes that the salts are mechanically carried into the steam and that some become dry salts as the water present is evaporated in the superheater. Sodium hydroxide, however, does not dry but retains an appreciable amount of water and this passes through the superheater as small sticky droplets which later adhere to the turbine blades. Furthermore, if enough dry or powdery salts are present, they prevent the pasty material from adhering to the turbine blades. Thus, under certain conditions, if the sulphate content of the boiler water is high in respect to the sodium hydroxide, deposits do not form. This theory, however, does not explain the presence of almost pure silica deposits on turbine blades.

5. The "Molten Salt" theory considers that small salt grain particles remaining from the evaporated boiler water droplets, after superheating, have a definite melting point which may be below the superheat temperature. As the steam passes through the turbine, the temperature is reduced and the salts crystallize out. However, since silica has a very high melting point, this theory does not explain the formation of pure silica deposits on the turbine blading.

The investigation reported by Professor Straub was undertaken in an effort to determine the actual manner in which these salts enter the steam and their relationship to turbine deposits. The first series of tests was conducted on a small electrically heated boiler capable of generating steam up to 2800 lb pressure at low steam release velocities and with the steam outlet a considerable distance above the water level in order to minimize or prevent the entrainment of boiler water in the steam. The second series of tests was conducted with the boiler redesigned so as to permit operation up to critical pressure, to superheat it, and pass the steam over a stationary turbine blade. Higher steam release velocities were attainable.

Preliminary runs were made with pure distilled water, the condensed steam degassed and cooled and both its conductance and pH measured. A high-quality steam (0.25 micromhos) at pressures up to 2800 lb was obtained.

Then runs were made, at low steam release velocities, with definite amounts of sodium hydroxide and other salts added to the boiler water. With sodium sulphate in the boiler water at concentrations up to 2400 ppm and at pressures up to 2000 lb, the steam contained less than 0.01 ppm of dissolved solids. At 1550 lb pressure and 650 ppm boiler-water concentration there was still less than 0.01 ppm dissolved solids in the steam. But when the pressure was raised to 2370 lb, the sodium hydroxide in the steam measured 0.08 ppm with the same boiler water concentration. At 2700 lb pressure, the sodium hydroxide in the steam reached 0.28 ppm with a boiler-water concentration of only 400 ppm.

The presence of these salts in the steam could hardly have been attributed to mechanical entrainment, in view of the low steam release velocities and the height of the steam take-off above the water level. Moreover, since sodium sulphate was carried in the steam, and this has a melting point of 1623 F, the theory of vaporization did not appear to apply.

In the second series of tests, with the boiler modified, runs at 2368 lb abs and 660 F gave steam having a specific conductance of 0.42 micromhos even when sodium chloride was present in the boiler water in concentrations up to 7000 ppm. The maximum concentration of chlorides measured in the steam under these conditions was 0.10 ppm.

The boiler was so constructed that the steam release at and above the water level was visible through water

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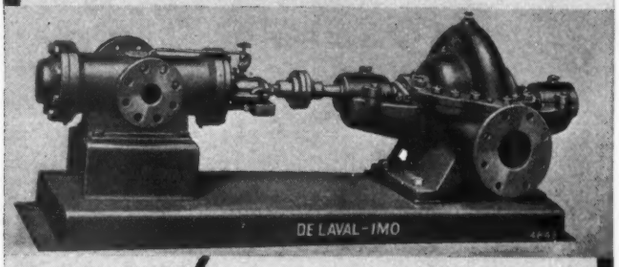

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level glasses on each side. It was observed that as the pressure was increased there was a decrease in the size of the bubbles; the water level became more stable; heat convection waves were visible as the pressure approached 2400 lb; and slight fluctuations in temperature, at the higher temperatures, caused very rapid fogging or condensation of the steam in droplets.

This condensation appeared to be the key to the discrepancy noted between the results obtained and those reported in a paper by Dr. F. Spillner in *Die Chemische Fabrik* of November 2, 1940. The latter found around 50 ppm of NaCl in the saturated steam at 660 F with boiler water containing 5000 ppm NaCl in contrast with a maximum concentration in the steam of 0.10 ppm NaCl in the tests here reported. It was noticed that Dr. Spillner had removed the steam from the autoclave in such a manner that no condensation could take place whereas in the present tests there could be appreciable condensation of the steam with a subsequent "washing" with condensed steam before sampling. When the unit was modified so that there would be little, if any condensation before sampling, the results were substantially in agreement with those of Dr. Spillner. That is, at 550 and 600 F, the concentration of the salt in the steam was proportional to that in the boiler water up to around 1000 ppm in the water, above which it appeared to be constant. At 660 F the amount in the steam appeared to be almost proportional to that in the boiler water up to a concentration of 8600 ppm NaCl in the boiler-water. In further test runs with the heaters off the top, so as to allow condensation, the salt in the steam dropped to almost zero, even at 660 F.

These results indicate that the NaCl in the steam is proportional to that in the boiler water up to about 1000 ppm in the latter; and that at 1250 lb pressure and 200 ppm boiler-water concentration, the steam would show less than 0.05 ppm. However, at 2400 lb the NaCl in the steam would be around 1.5 ppm for the same boiler-water salt concentration. Were the steam to be washed with feedwater, this solubility would be reduced to a very low value.

The tests were extended to cover sodium hydroxide and the same effect was observed.

Conclusions

The steam leaving the boiler along with entrained water appears to evaporate the salt to a solid state as it passes through the superheater. The superheated steam dissolves the salt and carries it in solution. As the steam drops in pressure and temperature in its passage through the turbine, a condition is reached where the saturation point occurs and the salt begins to crystallize in the blade. Certain salts will adhere while others may pass through entrained in the steam.

The data obtained indicate that steam has the ability to dissolve salts present in boiler water, and that the degree of solubility with normal boiler water does not become appreciable until pressures of around 2400 lb are reached.

The solubility of the salts in the steam is affected by both pressure and temperature. Thus steam will dissolve more salt at high pressure and on cooling will reach a stage of supersaturation which will be conducive to turbine blade deposits.

Combustion Engineering Awarded Army-Navy "E"

Up she goes! Representitives of Combustion's workers raise the "E" pennant. The colored worker has had 48 years of service.

ON NAVY DAY, October 27, the Army-Navy "E" Award was presented to the Hedges-Walsh-Weidner Division of Combustion Engineering Company, Inc. The presentation was made in a colorful out-of-door ceremony at the plant in Chattanooga, Tenn., attended by some 3000 employees and their families.

Lt. Colonel J. C. Shouvlin of the Cincinnati Ordnance District made the presentation address, in the course of which he said, "Fortunately, this company happens to be one that started producing for war over three years ago. The production we have gotten out of your company has been worth its weight in gold. It is worth its weight in gold because the Government had the foresight to order, three years ago, what it wanted and the management of your company showed the proper disposition at all times to cooperate with the Government. Without full cooperation we could not have been in the state of readiness we are in today."

The acceptance address was delivered by A. J. Moses, Vice-President and General Manager of the company's Chattanooga plant. In expressing the spirit in which the Award was accepted, Mr. Moses said, "There is only one issue for Americans today. It is a very simple issue which all of us can understand. ARE WE PREPARED AND DETERMINED TO DO OUR DUTY AS AMERICANS? If we are, we shall let no personal or group consideration deter us from doing our best to back up our fighting forces—not some of the time, or most of the time, but ALL of the time until complete and final victory is ours."

Presentation of the "E" pins to five selected employees was made by Lieutenant Commander J. H. Gibbons, U. S. N. R.

The largest of the company's four manufacturing units, the Hedges-Walsh-Weidner Division, is operating 24 hours a day, 7 days a week, supplying boilers and related equipment for practically all types of war production plants. Included in this category of work are boiler units and special pressure vessels for most of the larger powder plants. The company is also supplying complete boiler units for naval and cargo ships, its contracts covering nearly 40 per cent of the entire shipbuilding program of the U. S. Maritime Commission. It is a recent recipient of the Maritime Commission's "M" Award.

Officers representing the Army and Navy join with participants in the program for a group picture at Combustion's "E" presentation ceremony.

Some 3000 Combustion workers and their families at the Army-Navy "E" presentation ceremonies.

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A.S.M.E. Annual Meeting Program

The program for the A.S.M.E. Annual Meeting, to be held in New York, November 30 through December 4, comprises more than a hundred technical papers, several panel discussions, and talks by government officials and industrial leaders. It is more extensive than any heretofore presented at an Annual Meeting and will involve five concurrent sessions throughout the week. As would be expected, war production in its various phases and man power will keynote the program, although there will be the usual number of technical papers sponsored by the professional divisions. All sessions will be held at the Hotel Astor. That part of the program dealing with subjects relating directly or indirectly to power is as follows:

MONDAY, November 30

8:00 p. m.

"The Holding Power and Hydraulic Lightness of Expanded Tube Joints—Analysis of the Stress and Deformation," by J. N. Goodier and G. J. Schoessow.

"Experimental Investigation of Tube Expanding," by E. D. Grimison and G. H. Lee.

"Practical Aspects of Making Expanded Joints," by C. A. Maxwell.

TUESDAY, December 1

9:30 a. m.

"The Effect of Installation on the Coefficients of Venturi Meters," by W. S. Pardoe.

"An Investigation on the Metering of Pulsating Flow," by S. R. Beitler.

"A Progress Report on Flow-Nozzle Coefficients," by H. S. Bean.

"Developments in Spreader Stoker Firing," by R. L. Beers.

2:00 p. m.

"Measurement of High Temperatures in High-Velocity Gas Streams," by W. J. King.

"Desirable Characteristics of Valves and Final Control Elements for Cascade Control," by P. W. Keppler.

"Development and Performance of a Coal-Fired Unit Heater," by R. M. Rush.

"Static Friction," by Walter Claypoole.

"Experiments on Bearing Performance," by P. G. Exline.

8:00 p. m.

"The Application of Turbine Supervisory Instruments to Power-Generating Equipment," by J. L. Roberts and H. M. Dimond.

"1825-Lb. Pressure Topping Unit with Special Reference to Forced Circulation Boiler," by F. S. Clark, F. H. Rosencrants and W. H. Armacost.

WEDNESDAY, December 2

9:30 a. m.

"Panel Discussion on Boiler-Water Problems in Connection with High-Temperature, High-Pressure Steam Generation."

"Investigation of Large Diesel-Engine Wristpins, Pistons and Crankcase Explosions," by Frank E. Faast.

"Rating Supercharged Engines on the Basis of Mean Temperature of the Cycle," by Ralph Miller.

"Inlet-Air-Temperature Corrections in a Roots Supercharger," by Frederick A. Hiersch.

"Definition of Volumetric Efficiency of Internal-Combustion Engines," by P. H. Schweitzer.

2:00 p. m.

"A Practical Way to Prevent Embrittlement Cracking," by A. A. Berk and W. C. Schroeder.

"Boiler Embrittlement," by Carl A. Zapffe.

THURSDAY, December 3

9:30 a. m.

"Centrifugal Pump Performance as a Function of Specific Speed," by A. J. Stepanoff.

"Tests of Steam Pipe Insulation," by E. A. Allcut.

2:00 p. m.

"Symposium on Feedwater Heating Cycles."

8:00 p. m.

"Symposium on Marine Power," six papers dealing with marine diesels.

"Panel Discussion on Shell and Tube Heat Exchangers."

"Corrosion of Unstressed Alloy-Steel Specimens by Steam at Temperatures up to 1800 F," by G. A. Hawkins, H. L. Solberg, J. T. Agnew and A. A. Potter.

"Effect of Dioxidation Practice on Creep Strength of Carbon-Molybdenum Steel at 850 and 1000 F," by R. F. Miller.

FRIDAY, December 4

9:30 a. m.

Further discussion on paper, "Studies of Heat Transmission Through Boiler Tubing at Pressures from 500 to 3300 Psi," by Messrs. Davidson, Hardie, Humphreys, Markson, Mumford and Ravese.

Of general interest to many will be a motion-picture film showing the Sikorsky helicopter, accompanied by a talk by its inventor on "Creative Engineering, Invention and Intuition." Among other notable talks will be one on Wednesday morning by W. L. Batt of WPB on "Management Attitudes."

The Annual Business Meeting of the Society will be held at 4 p.m., Monday, November 30, and this will be followed by the Local Sections Delegates Conference. Various luncheons are scheduled throughout the week and the Annual Banquet will take place on Wednesday evening at the Hotel Astor.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1942 Water Tube		1941 Water Tube		1942 Fire Tube		1941 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.....	202	1,637,588	170	968,275	53	61,990	89	123,459
Feb.....	238	1,557,004	97	847,331	59	84,660	81	104,622
Mar.....	273	1,520,654	138	988,037	166	92,999	86	89,324
Apr.....	430	2,441,668	159	802,993	57	81,402	129	151,636
May.....	160	1,280,558	134	850,659	63	90,069	114	154,964
June.....	139	847,562	141	743,762	61	75,831	114	134,880
July	134	891,224	184	1,184,984	48	56,996	94	121,884
Aug.....	‡114	‡936,660	113	749,405	26	30,228	51	101,284
Sept.....	48	378,096	120	843,896	337	275,808	61	63,385
Jan.-Sept. Incl....	1,738	11,491,014	1,256	7,979,342	870	849,983	819	1,045,438

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period January to September (incl.) 1942, 97,480,000 lb per hr; in 1941, 81,164,000 lb per hr.

†Mechanical Stoker Sales

	1942 Water Tube		1941 Water Tube		1942 Fire Tube		1941 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.....	87	42,876	77	41,975	154	23,550	94	14,036
Feb.....	131	55,001	60	27,736	185	26,889	117	14,774
Mar.....	84	46,055	69	31,342	212	31,715	146	21,552
Apr.....	102	49,061	75	34,832	313	39,877	147	20,555
May.....	125	44,069	90	43,971	206	33,566	144	19,267
June.....	123	48,267	136	50,896	296	49,760	264	42,619
July.....	131	59,376	113	50,108	297	45,902	290	40,943
Aug.....	94	40,619	96	41,882	295	49,725	391	49,547
Sept.....	78	37,081	83	33,663	295	44,910	335	49,559
Jan.-Sept. Incl.	955	422,405	799	356,405	2,256	345,894	1,928	272,852

† Capacity over 300 lb of coal per hr.

Pulverizer Sales

	1942 Water Tube			1941 Water Tube			1942 Fire Tube			1941 Fire Tube		
	No. (N)	No. (E)	Lb Coal/hr	No. (N)	No. (E)	Lb Coal/hr	No. (N)	No. (E)	Lb Coal/hr	No. (N)	No. (E)	Lb Coal/hr
Jan.....	102	3	1,071,340	39	—	462,990	—	—	—	—	1	1,000
Feb.....	21	1	246,520	42	4	734,200	—	—	—	—	—	—
Mar.....	31	7	360,620	31	3	739,700	1	—	13,300	—	—	—
Apr.....	49	8	845,740	14	8	225,740	—	—	—	1	—	2,800
May.....	26	4	373,962	54	10	777,320	—	—	—	—	4	7,000
June.....	24	3	323,500	28	24	523,540	—	—	—	—	1	1,000
July.....	21	11	300,880	57	7	828,640	—	—	—	—	1	600
Aug.....	3	12	180,460	30	5	456,480	—	—	—	—	1	800
Sept.....	16	12	401,900	38	2	480,030	—	1	700	—	—	—
Jan.-Sept. Incl....	293	61	4,104,922	333	63	5,228,640	1	1	14,000	1	8	13,200

(N)—New Boilers; (E)—Existing Boilers.

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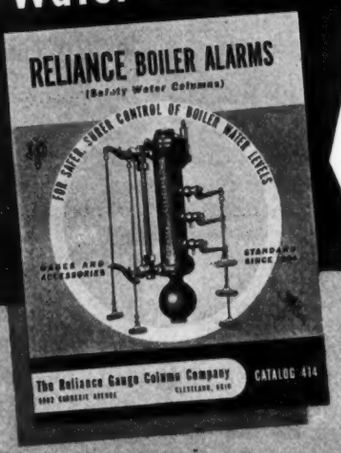
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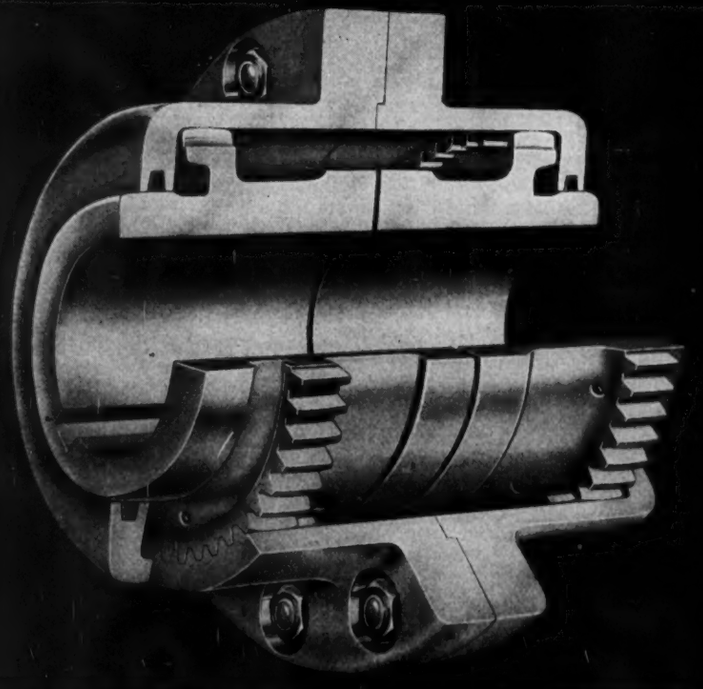


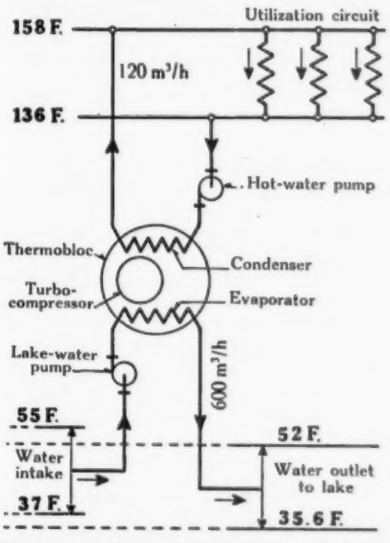
A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

Heat Pump Saves Fuel in Swiss Silk Mill

By means of the heat pump, large quantities of low-head heat, at a temperature too low to be useful, can be converted into useful heat at a high-temperature level, with the expenditure of a relatively small amount of electric power. This offers certain possibilities in localities where coal is scarce, where there is abundance of low-head heat and where there is demand for hot water at 160 to 175 F, or less, for heating or process requirements. Such conditions exist in certain parts of Switzerland and two such installations are described in the April 1942 issue of *Brown Boveri Review*, copies of which have recently reached this country. One of these installations, which is briefly described in the following, is in a silk mill at Steckborn, Switzerland.



Diagrammatic arrangement of heat pump with auxiliaries

This plant comprises two Brown Boveri "Thermoblocs" with a maximum capacity of 1,700,000 kcal (6,745,600 Btu) per hour which are used to prepare hot water for heating and process. In order to heat up 120 cu m of water per hour to 158 F, 600 cu m of water per hour is taken from Lake Constance at a temperature varying between 37 and 55 F and allowed to flow back after being cooled down by 2 or 3 deg. F. The diagram shows how the available heat is carried from the lower to the higher temperature level by electric power used to drive a compressor.

The heat in the lake water is taken up by a refrigerating agent (CH_2Cl_2) which vaporizes at a low temperature and this heat is surrendered in the condenser to the water which it is desired to heat for process. The power required to drive the heat pump ranges from 514 to 590 kw.

There is a three-speed reduction gear which allows of running the heat pump at three different speeds to permit of adjusting the work conditions to the variations in temperature of the lake water at different seasons.

It is estimated that each of the two sets saves about 1400 tons of coal annually when the plant is in continuous operation.

FPC to Supervise War Power Contracts

The President has designated the Federal Power Commission as the central agency of the Government to determine the cheapest source of power supply for the fulfillment of war contracts.

Chiefly concerned with this new order are the procurement branches of the War Department, the Navy Department, Defense Plant Corporation, Maritime Commission, Federal Works Administration and the Federal Housing Administration as well as the War Production Board. The procedure involves:

1. Designation by each of the foregoing of a power procurement officer to handle all contracts and arrangements for electric power.
2. Each agency is to report promptly to the power procurement officer each proposed procurement of power in excess of a reasonable minimum which involves Government approval or Government obligation, such reports to include all essential facts in accordance with forms approved by the Federal Power Commission.
3. The power procurement officers are to refer such reports promptly to the Federal Power Commission, together with the proposed contracts, for determination whether cheaper power supply is available and the latter will then issue the necessary orders after consultation with the War Production Board as to priorities and allocations.
4. The Federal Power Commission is to determine whether the proposed rates and conditions are reasonable and, if in its opinion they are unreasonable, it will fix the proper terms and cooperate with the power procurement officer in effectuating arrangements necessary for securing power on the best possible terms.
5. The Commission will review and renegotiate existing contracts in accordance with the foregoing.

This latest order would appear to be a revision of the arrangement effected last April, defining the relative scopes of WPB and FPC. In that agreement, it will be recalled, the Power Branch of the War Production Board was given jurisdiction over power supply for war production.

Cut in Copper and Steel for Maintenance and Repair

The amount of scarce metals that public utilities may use for maintenance and repair of transmission and distribution systems during the last quarter of 1942 has now been cut 40 per cent. The same reduction has been made in permissible inventories. Previously, a utility could use as much scarce metal for maintenance and repair as it used during the corresponding quarter of 1940. This applies chiefly to copper and steel.

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NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

American Standards for 1942

The American Standards Association has announced the publication of its newest "List of American Standards for 1942." More than 550 standards are listed, of which 71 represent new and revised standards approved since the last (February 1942) issue. One section is devoted to American Safety Standards; War Standards are under a separate heading. Other standards include: definitions of technical terms; specifications for metals and other materials; methods of test for the finished product; dimensions, etc. Requests should be addressed to the American Standards Association, 29 West 39th Street, New York, N. Y.

Arc-Welding Accessories

A profusely illustrated 32-page bulletin (GEA-2704B) recently issued by the General Electric Company, presents a most complete line of General Electric arc-welding accessories. Among the listed items, which are completely specified and described in detail, are: goggles, observation shields, ventilated head protectors, chrome-leather protective clothing, flame-proofed welding screens, ultra-violet-ray protective paint, metal and carbon electrode holders, clamps, cable connectors, brushes, chippers, electrode carriers, and fillet-weld gages. Also listed is General Electric's 200-page arc-welding manual. A price list and order blanks accompany the bulletin.

Coal Crushers and Breakers

The McNally Pittsburgh Mfg. Corp. has issued a 20-page bulletin (No. 342) which presents a full line of coal crushing and breaking equipment. This includes: double-roll breakers for standard and heavy duty, stoker coal crushers, vertical pick breakers, single-roll crushers and "multiplex" single-roll crushers. The bulletin is profusely illustrated with halftones and line drawings. Capacities are given in relation to size of product and variable dimensions are also listed.

Centrifugal Pumps

The Allis-Chalmers Mfg. Company has issued a profusely illustrated 8-page bulletin (B6059-H) covering a complete line of centrifugal pumps. Construction features, sizes and capacities are listed in a manner which simplifies the selection of pumping equipment for specific needs. Various types of pumps include: single and double suction, single and multi-stage, mixed and axial flow, combined units and special pumps for special problems. Recommended applications for the one-package pump unit, the Electrifugal, are also included.

Motor Fitness Manual

Motor fitness requirements is the subject of a new 40-page illustrated bulletin (GED-1017) recently issued by the General Electric Company. The bulletin is arranged for quick reference and discusses the following subjects in a comprehensive and informative manner: How to get the most service out of old and new motors, "switching" motors from one job to another, and equipping old machines with new motors. Also, selection and application of motors, various types of motor enclosures, secondary ratings of standard integral-hp motors, ways to determine WR^2, motor maintenance, full load currents of motors, selection of a-c control, and the use of the hook-on voltammeter. A supplement explains how to save critical motor materials, including WPB recommendations, and information on the use of load-time-temperature charts.

Multiple V-Belt Drives

A colorful 16-page booklet entitled "23 Ways to Conserve the Life of Your Multiple V-Belt Drives" has been received from the Multiple V-Belt Drive Association. Its sole purpose is to educate power users in proper procedure of selection, installation and maintenance of V-belt drives in order to obtain the maximum life out of every V-belt. The presentation of the subject is excellent as the text is simple, non-academic and enlivened by attractive and colorful sketches. Recommendations given will help to reduce needless waste of rubber in the present emergency. The booklet is free and obtainable from the Multiple V-Belt Drive Association, 140 S. Dearborn Street, Chicago, Ill.

Non-Deaerating Heater Standards

The Heat Exchange Institute has published a 12-page booklet entitled "Standards of Heat Exchange Institute—Non-Deaerating Heater Section." This bulletin deals with: Nomenclature, Definitions, Types and Standards of Construction, Rating Standards and Guarantees, Accessories, and also includes a Typical Specification. In stiff paper covers. Price —75 cents.

pH Value

An informative 12-page booklet entitled "What Every Executive Should Know About pH" has been published by the National Technical Laboratories for the purpose of giving a quick, not-too-technical picture of what pH is, and how pH control may be used to advantage. A chart is given which shows the relationship of pH values to relative acidities and alkalinities. Three types of Beckman pH Meters are illustrated by photographic halftones.

Standard Code for Testing Hot Water Unit Heaters

This code has been prepared and issued by the Industrial Unit Heater Association in order to establish a standard method of testing unit heaters using hot water as a heating medium. The subjects covered by the code include: Definitions, Rating, Standard Basis of Rating, Outline of Tests, Equipment for Testing, Test Procedure, and Computation of Results.

Thermocouples

A new 6-page bulletin, interpreting the recent WPB Conservation Order L-134 as it applies to thermocouples and thermocouple protection tubes for pyrometric instruments, has been issued by the Wheelco Instrument Company. The bulletin is styled as a supplement to this company's Thermocouple Data Book S2-3 and provides a convenient guide in the selection of the most satisfactory thermocouples, thermocouple protecting tubes and lead wire for a given instrument application in line with restrictions placed upon certain critical materials.

V-Belt Drives

A new Texrope V-Belt Drive bulletin (B6051-C) has been received from the Allis-Chalmers Mfg. Company. This 12-page wartime catalog reduces a wealth of engineering information to simplified charts and tables for quick selection of power transmission units. List prices, stock sizes, dimensions and construction details are included for all Texrope drives. Vari-pitch sheaves and drives and the vari-pitch speed-changers are also described.

Water Analyses

A profusely illustrated 20-page booklet, presenting apparatus and chemicals used for industrial water analyses, has been received from W. H. and L. D. Betz. The book features the test sets required for such determinations as hardness, alkalinity, phosphate, sulphate, dissolved oxygen, pH value, silica, and others. In addition, numerous comparators, photometers, turbidimeters, etc., are described and a separate price list of apparatus and chemicals is also given.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

New Commercial Technical Dictionary—Spanish-English English-Spanish

Compiled by Antonio P. Guerrero

Because of the wide geographical distances between the Spanish speaking countries (which has given rise to various dialects and pronunciations) and also because of the many industries that have sprung up in these countries in recent years which involve machinery and equipment from the United States, there has arisen a vital need for a standardized terminology for technical and commercial words. Recognizing this need the author, a Spanish engineer, has compiled this dictionary and has included all the needed modern words referring to mechanics, mechanical engineering, shipbuilding, etc., and also marine and naval terms, fully defined.

The book is made up in three parts: Part I—Spanish-English, Part II—English-Spanish and Part III—Conversion Tables of Weights, Measures and Monetary units. The author has also included a page of special explanatory notes which fully explain the make-up of the dictionary and the manner in which it can be best consulted. This work is thumb indexed, flexibly bound and Morocco finished. Size 6 × 9. Price $10.00.

A.S.T.M. Standards on Coal and Coke

The American Society for Testing Materials has issued the 1942 edition of its Standards on Coal and Coke, covering methods of sampling and testing, specifications and definitions of terms. A number of changes appear in this edition including modifications in standard methods of laboratory sampling and analysis of coal and coke.

The compilation includes specifications for classification of coals by rank and by grade, requirements for gas and coking coals, and specifications for sieves for testing purposes. The methods which are coming into widespread use cover coal sampling procedure and methods of test for grindability (ball-mill and Hardgrove-machine methods), sieve analysis, agglutinating value, drop shatter test, an index of dustiness of coal and coke, and other corresponding tests for coke with additional tests for volume of cell space. In this field definitions are important and there are three such standards.

Copies of this 130-page publication may be obtained from the A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia, Pa. Paper covers; size 6 × 9. Price $1.35 per copy.

United States Government Manual

The Fall edition of the *United States Government Manual*, a 700-page reference book on the creation and organization functions and activities of the Federal Departments and Agencies, has been announced. The new edition, which contains changes through September 1, includes statements on all the branches of Government, a list of principal officials, separate sections on the emergency war agencies, organization charts, publications and commonly used abbreviations. It also contains an appendix on agencies absolished, transferred or consolidated since 1933.

The *United States Goverment Manual* may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., or at the U. S. Information Center, 1400 Pennsylvania Avenue N.W. Single copies cost $1.00; subscriptions covering the three editions a year cost $2.75.

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WRITE FOR CATALOG

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New Order Affecting Power Equipment

Procedures for the production scheduling of heavy power and steam equipment are established in Amendment No. 4 to Limitation Order L-117, issued by the War Production Board. Manufacturers of power equipment will submit monthly reports covering existing production schedules. These schedules will be reviewed and, if necessary, revised by the War Production Board.

Production scheduling has been devised as a means of reconciling the heavy demand for power equipment with the limited production facilities of the industry. Production schedules must be so arranged as to assure delivery of large items of power equipment in time to meet the requirements of our national power program. Furthermore, since a single-power installation may require many items of equipment produced in separate manufacturing plants, it is important to integrate the delivery dates of such items.

The new amendment extends to a variety of power equipment controls similar to those which now apply to turbines under an earlier War Production Board order. Among the items of equipment covered by the amendment are large steam generating units, surface condensers, steam engine generator units, frequency changers, synchronous condensers and transformers.

Coal per Kw Hr Now 1.34 Lb

The Federal Power Commission has just issued a report covering the consumption of fuel for the production of electric energy in 1941. That produced for public use by all types of fuel, excluding wood and wood waste, totaled 116,167,273,000 kw hr during the year while the consumption of coal and coal-equivalent oil and gas amounted to 77,995,749 tons. From these figures the average coal consumption per kilowatt-hour was 1.34 lb, the lowest on record.

Following is the fuel consumption data for 1941:

Lignite	(short tons)	1,248,253
Anthracite	" "	2,895,725
Bituminous	" "	60,612,292
All coal	" "	64,756,270
Oil (barrels)		20,247,931
Gas (mcf)		205,155,517

The electricity generated by coal amounted to 96,448,324,000 kw hr; that by oil 7,563,089,000 kw hr; and that by gas 12,155,860,000 kw hr. These figures represent net station output.

Figures for September 1942 were also available and totaled 15,922,893,000 kw hr which represented an increase of 12.6 per cent over that for September 1941. Of this amount, water power accounted for 5,191,697,000 kw hr, or 32.6 per cent of the total.

For the 12 months ending September 30, 1942 the total production for public use was 180,306,365,000 kw hr which was an increase of 13.4 per cent over the preceding 12-month period.

The capacity of electric generating plants on September 30, 1942, was 45,961,230 kw, representing a net increase of 160,700 kw during the month.

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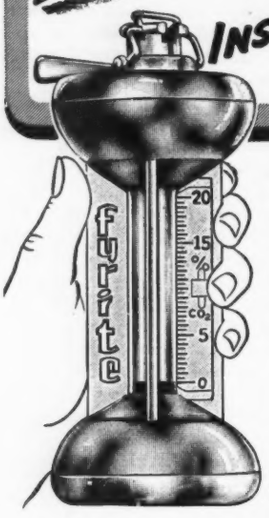

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Personals

W. L. Manly has been named manager of the Allis-Chalmers Feedwater Treating Department. As field engineer from 1937 to 1940, Mr. Manly served many types of plants throughout the Middle West and since 1940 has been engaged in conducting research on feedwater problems.

George M. Stevens has been appointed as acting manager of the General Electric Company's River Works and N. M. Du Chemin as acting manager of that company's West Lynn Works, succeeding the late Nelson J. Darling who was manager of both plants.

Harry F. Boe, Manager of the Westinghouse District Repair and Manufacturing Department at East Pittsburgh, has been elected a vice president of that company. He has been with the Westinghouse Company since 1901.

Gerard Swope, President of the General Electric Company, has been selected as the recipient of the Hoover Medal which will be presented at the Winter Convention of the A.I.E.E. This medal is awarded annually for distinguished engineering and public service by a board representing the A.S.M.E., the A.I.E.E., the A.S.C.E. and the A.I.M.E. Herbert Hoover was the first to receive this medal in 1930.

Frederick L. Ray, past president of the NAPE, for a number of years superintendent of power plants of the Union Traction Company of Indiana, and lately in charge of the Anderson, Ind., Sewage Treatment plant, recently retired from active service.

Dr. William M. White, widely known hydraulic engineer has retired after a number of years as manager of the Hydraulic Turbine Department of Allis-Chalmers Company. He has been succeeded as hydraulic department manager by **J. F. Roberts,** formerly head hydraulic engineer of TVA; and **H. P. Binder** has been made manager of the Centrifugal Pump Department of the Company.

Obituaries

Floyd L. Carlisle, Chairman of the Board of the Consolidated Edison Company of New York and one of the nation's leading utility executives, died at Glen Cove, Long Island, on November 9 at the age of 61. After graduation from Cornell University in 1903, Mr. Carlisle took up the study and practice of law but soon switched to investment banking. In this connection he entered the utility field in 1920 and soon became identified with the leading utility systems in New York State.

Nelson J. Darling, Manager of the General Electric Company's West Lynn and River Works, died on October 26 at his home in Beach Bluffs, Mass., after an illness of several months. He was 58 years old. Upon graduation in mechanical engineering from Cornell University in 1907, he entered the employ of General Electric Company and served in various capacities with that company until his death.

William Salt, for many years head of the Service Department of the De Laval Steam Turbine Company, died suddenly on October 31. He was one of the oldest employees in point of service, having been associated with that company for more than forty years.

Prof. R. H. G. Edmonds, of the Mechanical Engineering Department of the University of Washington, died on October 4.